ПЕРМСКИЙ
ГОСУДАРСТВЕННЫЙ
НАЦИОНАЛЬНЫЙ
ИССЛЕДОВАТЕЛЬСКИЙ
УНИВЕРСИТЕТ

А. Ф. Корлякова

ИНОСТРАННЫЙ ЯЗЫК (АНГЛИЙСКИЙ)

ENGLISH READER FOR STUDENTS OF RADIOPHYSICS

ИЗДАТЕЛЬСКИЙ ЦЕНТР
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Основная цель пособия – развитие навыков чтения научно-исследовательской литературы и подготовка студентов физического профиля к чтению оригинальной литературы по специальности.

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1. WHAT ARE JOSEPHSON JUNCTIONS? HOW DO THEY WORK?

Leigh John Martinson

Richard Newrock, a professor of physics at the University of Cincinnati, has studied the physics of superconducting materials for 20 years. Here is his explanation.

A Josephson junction is made by sandwiching a thin layer of a nonsuperconducting material between two layers of superconducting material. The devices are named after Brian Josephson, who predicted in 1962 that pairs of superconducting electrons could “tunnel” right through the nonsuperconducting barrier from one superconductor to another. He also predicted the exact form of the current and voltage relations for the junction. Experimental work proved that he was right, and Josephson was awarded the 1973 Nobel Prize in Physics for his work.

To understand the unique and important features of Josephson junctions, it’s first necessary to understand the basic concepts and features of superconductivity. If you cool many metals and alloys to very low temperatures (within 20 degrees or less of absolute zero), a phase transition occurs. At this “critical temperature,” the metal goes from what is known as the normal state, where it has electrical resistance, to the superconducting state, where there is essentially no resistance to the flow of direct electrical current. The newer high-temperature superconductors, which are made from ceramic materials, exhibit the same behavior but at warmer temperatures.

What occurs is that the electrons in the metal become paired. Above the critical temperature, the net interaction between two electrons is repulsive. Below the critical temperature, though, the overall interaction between two electrons becomes very slightly attractive, a result of the electrons’ interaction with the ionic lattice of the metal.

This very slight attraction allows them to drop into a lower energy state, opening up an energy “gap.” Because of the energy gap and the lower energy state, electrons can move (and therefore current can flow) without being scattered by the ions of the lattice. When the ions scatter electrons, it causes electrical resistance in metals. There is no electrical resistance in a superconductor, and therefore no energy loss. There is, however, a maximum supercurrent that can flow, called the critical current. Above this critical current the material is normal. There is one other very important property: when a metal goes into the superconducting state, it expels all magnetic fields, as long as the magnetic fields are not too large.

In a Josephson junction, the nonsuperconducting barrier separating the two superconductors must be very thin. If the barrier is an insulator, it has to be on the order of 30 angstroms thick or less. If the barrier is another metal (nonsuperconducting), it can be as much as several microns thick. Until a critical current is reached, a supercurrent can flow across the barrier; electron pairs can tunnel across the barrier without any resistance. But when the critical current is exceeded, another voltage will develop across the junction. That voltage will depend on time – that is, it is an AC voltage. This in turn causes a lowering of the junction's critical current, causing even more normal current to flow—and a larger AC voltage.

The frequency of this AC voltage is nearly 500 gigahertz (GHz) per millivolt across the junction. So, as long as the current through the junction is less than the critical current, the voltage is zero. As soon as the current exceeds the critical current, the voltage is not zero but oscillates in time. Detecting and measuring the change from one state to the other is at the heart of the many applications for Josephson junctions.

Electronic circuits can be built from Josephson junctions, especially digital logic circuitry. Many researchers are working on building ultrafast computers using Josephson logic. Josephson junctions can also be fashioned into circuits called SQUIDs – an acronym for superconducting quantum interference device. These devices are extremely sensitive and very useful in constructing extremely sensitive magnetometers and voltmeters. For example, one can make a voltmeter that can measure picovolts. That's about 1,000 times more sensitive than other available voltmeters.

A SQUID consists of a loop with two Josephson junctions interrupting the loop. A SQUID is extremely sensitive to the total amount of magnetic field that penetrates the area of the loop – the voltage that you measure across the device is very strongly correlated to the total magnetic field around the loop.

SQUIDs are being used for research in a variety of areas. Since the brain operates electrically, one can, by sensing the magnetic fields created by neurological currents, monitor the activity of the brain – or the heart. You can also use a SQUID magnetometer for geological research, detecting remnants of past geophysical changes of the earth's field in rocks.

Similarly, changes in the ambient magnetic field are created by submarines passing below the surface of the ocean, and the U.S. Navy is very interested in SQUIDs for submarine detection. SQUIDs are also of considerable use in the research laboratory in specially designed voltmeters, in magnetometers and susceptometers and in scanning SQUID microscopes. In this last instrument, a SQUID is scanned across the surface of a sample, and changes in magnetism at the surface of the sample produce an image.

Task 1

Which word means the following:

1. a regular arrangement of crystals;
2. the things that something in science regularly does;
3. to throw here and there , disperse;
4. to be greater than;
5. for this reason;
6. large enough to have an effect or be important

Task 2

Answer the following questions.

1. What happens to metals at very low temperatures?
2. What makes ceramic materials different?
3. What causes superconductivity?
4. What about resistance?
5. How does J -junction work?
6. Where is it used?
7. Why are electronic devices with J-junction so good?

2. HOW DOES THE RADIO PROPAGATE INDOORS?

It is well-known that radio wave reflect, not penetrate, when it hits a metallic surface. Anything that contains metal will reflect the radio wave, like the light fixture, file cabinet, computer, shelf, nail.....etc. When the radio is used indoors, these metallic objects will cause a lot of reflections and each reflection will arrive at the receiver with a slight time difference owing to the path difference. For example, an 1 foot path difference will cause approximately 1 nsec delay for 900 MHz radio. The slight time difference is usually enough to cause the signal to fluctuate and smear. This problem is known as the multipath effect. As shown in the following figure, a pulse of 100 nsec becomes a lump of signals as wide as 500 nsec at the receiving end in a typical office building. This kind of smearing and fluctuating cause higher error rates for the data and the timing to jitter and will affect the performance of most radios. OCI overcomes this problem by using a correlator that always selects and locks to the strongest peak signal.

The most severe impact of the multipath effect is the complete loss of signal. When two signals with the same amplitude from different paths arrive at the same time, the resulting composite signal could be a null if the two signals are out-of-phase.

Since the wavelength of the 900 Mhz radio is just about 1 foot, the possibility of having two signals with the same amplitude arriving with ½ foot path difference (out-of-phase) is quite high. If the receiver is close to the transmitter, the direct wave is usually much stronger than the reflect wave so that the multipath effect is not evident. But as the receiver moves farther away from the transmitter, it loses the dominant direct wave and the reflect waves prevails. And the reflect waves from different paths will have little difference in amplitude as the receiver is farther away from the transmitter. As a result, nulls prevails.

You can imagine the null zones caused by the multipath effect just like blowing bubbles at the bottom of the deep sea. The bubble is very small at the beginning and grows bigger and bigger as it ascents to the surface until it merges with the air. When the receiver is near the transmitter, the null zone is not evident. But as the receiver is moved away from the transmitter, the null zone grows in size until there is no communications at all. The null zone is not static, on the contrary, it always moves randomly. People’s movement, air’s movement and fan’s vibration will all cause the null to move around.

As you can see from the figure of the null zone, the receiver will not be affected much by the null-zone if it is placed inside the inner circle (robust zone). The receiver will still work from time to time even if placed outside the outer circle (forbidden zone) but the null-zone will severely deteriorate the radio's performance. To maintain a good quality of radio communications, it is important to identify the size of the robust zone, forbidden zone and identify the size of the robust zone, forbidden zone and the zone between them, the intermittent zone, and operate the radios only within the robust zone if possible.

To determine the size of each zone, the easiest way is to try a pair of the transmitter and receiver and see for yourself. This is because every building is different and the radio propagation is so much dependent upon the building. For example, a dry wall hardly has any effect on the radio propagation while a concrete wall attenuates the radio strength significantly. This is because the concrete wall contains more water than dry wall and water absorbs the radio wave.

To find out the size of the zones, you need to lock the transmitter on and move the receiver around the building. Most receivers have a carrier-detect light or a traffic light to indicate the presence of signal and it can be used as the indicator of the signal strength. Lay the receiver down on an open space, such as the top of the monitor or the top of the shelf and walk around it to see if it has any effect on the traffic light. You can even put your hand around the receiver (not touching the antenna). If the traffic light stays solid all the time then the receiver must be in the robust zone. Keep moving the receiver away from the transmitter until the receiver shows some flicking on the traffic light. The flickering indicates that a null is experienced.

Once a null is experienced, you can determined the size of the null by moving the receiver horizontally and vertically. Record the distance between the receiver and the transmitter, the maximum distance that you have to move the receiver to get it out of the null and the number of nulls you experienced in one cubic foot space. Then, move the receiver further away from the transmitter and repeat the above measurements again until you reach the forbidden zone. In this zone, the receiver will have a hard time to have a solid traffic light most of the time.

From the above records, you can figure out the size of robust zone as follows. The radius of the robust zone can be defined as the distance that the number of null is less than one in one cubic foot space and the size of the null zone is less than 0.5" in any direction. By this definition the null zone will occupy less than 0.01% of the space when it is in the robust zone. It also means that the failure rate caused by the null zone is less than 10-4 which is also the minimum error rate requirement for most radios.

It is most desirable to operate the radio within the robust zone. In this zone, the location of the radio is not critical if the radio is properly installed. If the radio has to be placed in the intermittent zone, some extra efforts are needed to assure a reliable radio link, such as moving the radio away from the shadow of other equipment or furniture, giving the radio as much free space around it as possible and putting the radio on top of a metallic surface. Keep in mind that the radio usually works better when it is placed farther away from the earth ground.

If you use a packet radio like LAWNII, you can reduce the packet size for the data to extend the coverage range. A small packet can survive a high error rate environment better than a large packet. The default packet size of the LAWNII is 256 bytes and it takes about 25msec to send the packet. If you use a packet size of 1, it will take less than 2.5 msec to send the packet and it can survive even at 10-3 error rate. Although a smaller packet is not an efficient way to send data due to the packet overhead (20 bytes), it is the most desirable way to send data from a low speed device such as a terminal.

Part 1 (up to <To determine the size of each zone>)

Task 1

Find words or expressions meaning the following:

1. Due to
2. rise and fall irregularly in number or amount
3. plain or obvious; clearly seen or understood
4. rise or move up
5. combine or cause to combine to form a single entity
6. quite the reverse; not at all
7. happening without method, disorderly
8. to worsen
9. strong and not likely to have problems

Task 2

Say whether the following is true, false or nor mentioned.

1. When radio waves reach a metal object they are partly absorbed by it.
2. Signals of equal amplitude arriving simultaneously from different paths always interfere with and cancel each other.
3. Modern concrete buildings can effectively reduce radio signals level due to reinforced concrete.
4. The greater the distance between the receiver and transmitter, the more likely the null zone is reached.
5. To have a good quality signal it is important to determine how big the three zones mentioned in the text are.

6. It is very easy to identify the size of the null zone as it is stable and doesn’t change its position in space.
7. The above phenomenon is widely used in stealth technologies.

Part 2 (from <to determine the size up to the end)

Find words or expressions meaning the following:

1. To influence
2. To weaken
3. Not enough
4. The number of times the signal is lost
5. Something that is worth having or doing because it is useful, necessary, or popular.
6. remember and take into account
7. an inefficient use
8. as soon as, when

3. ROLLTRONICS

The ability to print computer components, rather than making them on silicon wafers, could lead to lighter, cheaper computers – and you could even roll them up

1. WHICH invention had the greater impact: the printing press or the computer? Now imagine the potential impact of being able to combine the two and mass-produce computers almost as easily as newspapers, by printing them out on to thin films of plastic. That goal is what Rolltronics, a firm based in Menlo Park, California, has set out to achieve. It hopes to do this by extending a manufacturing technique, called “roll-to-roll” processing, so that it can be used to make computer components currently made in the form of silicon chips.
2. Roll-to-roll, as its name suggests, involves winding a continuous roll of flexible material (such as paper, plastic or metal foil) from one spool to another. Along the way, the material is subjected to a series of manufacturing steps. This approach is used to do things from printing newspapers to coating the insides of potato-crisp bags. Roll-to-roll manufacturing is also used to create flexible wiring, such as the transparent plastic “ribbon” connectors seen inside ink-jet printers. Rolltronics plans to take the next step, and extend the process to make flexible logic circuits, memory and other components.
3. Compared with the traditional approach, in which chips are made in batches in expensive factories, roll-to-roll processing involves far lower set-up costs, and can be more easily scaled up. So if it can be extended to produce computer components, it would be a cheap and fast – not to mention flexible – way to make electronic devices.
4. Soul of a new machine
5. A roll-up computer requires four distinct elements, says Michael Sauvante, Rolltronics’ boss. It needs flexible logic circuitry (to do the actual computing), flexible memory or storage, a flexible power source, and a flexible display. This last element is the focus of much attention from researchers trying to make “digital paper” that can be reconfigured to display arbitrary text and images. Rolltronics will leave others to develop this technology. The power source is also taken care of: several firms make thin-film batteries, which could be recharged by flexible solar cells already being manufactured in a roll-to-roll process by Iowa Thin Film Technologies (ITFT), a company based in Boone, Iowa. So Rolltronics has formed a partnership with ITFT to concentrate on the two remaining pieces of the puzzle: logic circuitry and storage.
6. Making flexible circuitry is difficult because logic circuits are traditionally made of transistors etched into a crystalline silicon wafer, which is rigid. But it is

possible to lay down a thin layer of silicon on a flexible plastic sheet, through a process called vacuum deposition. This silicon can then have transistors etched into it in the usual way. The problem, however, is that the silicon layer is amorphous, rather than crystalline. This affects its electrical properties, and means the transistors must be much larger, and switch much more slowly, than the transistors in a conventional chip – bad news if you are trying to build a computer. And while amorphous silicon can be turned into crystalline silicon by heating it, the high temperature required causes plastic to melt.

7. One way around this is to devise novel transistors that are themselves made of plastic, and therefore flexible. Rolltronics is taking a different approach. The company has licensed several patents from America’s Lawrence Livermore National Laboratory, where a team led by Paul Carey devised a clever way to turn amorphous silicon into the crystalline kind without high temperatures. By zapping the silicon with a laser it is possible to heat it, and cause it to form crystals, without melting the plastic. The resulting silicon can be treated with the usual chip-making processes to make transistors that are small, flexible and reasonably fast.

8. Rolltronics is working towards this flexible circuitry in two steps. To start with, it is developing a roll-to-roll process to make amorphous-silicon transistors on plastic film. Although these will be big and slow, they will have their uses. They could be used to make cheap radio-frequency identity tags – in essence, printable bar-codes that transmit an identifying code in response to a pulsed radio signal. Such tags, the size of a grain of rice, are currently used to tag everything from pets to televisions, and cost a few dollars apiece. Making cheaper tags using roll-to-roll would dramatically extend the range of uses. Amorphous-silicon transistors could also be used to make the “backplane” circuitry inside flat-panel computer displays. At the moment, this circuitry is made on glass. Using flexible plastic instead would be lighter, cheaper and less likely to break in a laptop computer that was dropped.

9. After that, says James Sheats, a researcher at Hewlett-Packard who is also Rolltronics’ chief technical adviser, the next step will be to apply Dr Carey’s work and make smaller, faster transistors on plastic film. Dr Sheats is optimistic that it will be possible to achieve performance equivalent to an Intel 80286 microprocessor (with a clock speed of around 10MHz) without too much difficulty. This would be enough for many applications, such as pocket calculators or handheld organisers, and there is room for further improvement.

10. That just leaves the memory, for which Rolltronics has licensed patents from a group of researchers at the University of Texas led by Allen Bard. Dr Bard and his colleagues have developed a novel form of memory that consists of a thin layer of organic liquid crystal sandwiched between two sheets of glass. Each glass sheet has rows of conducting wires running across it, and the two sets of wires are at right

angles, so that a voltage can be applied across the liquid crystal at any chosen intersection. Although the exact mechanism is still not entirely understood, it turns out that illuminating the liquid crystal, applying a voltage across a small region of it, and then turning off the light source causes a small amount of charge to be stored in that region. This means it can be used as a memory.

11. By replacing the glass sheets with plastic, Rolltronics plans to manufacture a flexible version of this memory using a roll-to-roll process. Its storage potential is enormous: Dr Sheats says that initially, a single layer of memory the size of a sheet of writing paper will be able to store one billion bytes (a gigabyte) of data. Admittedly, this unusual memory requires an internal light source, but the amount of illumination required is tiny and consumes less power than the logic circuits that are used to read data in and out. And as with the flexible circuitry, this technology has commercial applications on its own, in devices such as portable computers or digital cameras.

12. The long-term plan is to make a complete flexible computer in a laminated sandwich just a couple of millimetres thick. Of course, it is all still vapourware. But it is worth noting that one of Rolltronics' early supporters was Clayton Christensen of Harvard Business School, the champion of the notion of "disruptive technologies" – that is, innovations that take the incumbents in a particular industry by surprise. If Rolltronics' plan pans out, it could prove to be a canonical example.

Part 1 (from the beginning … to one way around it)

Task 1

Find words which mean the following:
1. instead of;
2. effect, influence;
3. to intend;
4. clearly different;
5. to include;
6. the antonym to flexible;
7. to become something different.

Task 2

Which paragraph
1. mentions the advantages of the new process;
2. explains possible applications of the new method;
3. mentions the problems the new method faces;
4. speaks about the thing the company is not going to do;

Task 3

Answer the following questions.
1. What is Rolltronics' aim?
2. Where does the roll-to-roll technique work?
3. What makes this approach so good?
4. Rolltronics deals with all the necessary components, doesn't it?
5. What are the necessary computer components?
6. What is the main obstacle in the way of creating flexible circuits?
7. How was the problem solved?

Part 2 (from <one way around it > up to the end)

Task 1

Find words which mean the following
1. to invent;
2. as a result;
3. to deal with smth in a particular way;
4. in answer, as a reaction; 5. a variety of different things or activities;
6. to make wider

Task 2

Answer the following questions.
1. How is the company trying to develop flexible circuitry?
2. Is there any use for amorphous silicon?
3. What fresults does the company hope to achieved with faster transistors?
4. What memory device did Rolltronics develop?
5. What makes the new memory tick?
6. What changes is Rolltronics planning to make in it?
7. How do you understand the phrase 'It is all vaporware'?

4. LIGHT WITHOUT LOGIC

Optical devices are finally going inside computers, but only in parts from the ‘Economist’ print edition

“GOD is light”, says the Bible. Light is also a source of inspiration in computing. Ever since the first optical transistors were developed in the late 1980s, researchers have dreamed of building a light-powered computer, radiating with knowledge. Yet this breakthrough has proved elusive. Now, however, new developments mean that optical technologies are starting to appear inside computers. The all-optical computer remains a dream, but selected components that can work with light will make their way into computers ever more deeply.

It is easy to see the attraction of replacing electrons, which travel along copper wires and make today’s computers tick, with photons. These particles of light are the fastest things in the universe, so an optical computer could theoretically process information at speeds that make even a supercomputer look glacial. So far, however, optical technology has been confined mostly to telecoms networks and some of the cabling in data centres. Photons are ideal for piping information over long distances. They whizz through optical fibres, rarely getting lost or interfering with one another (which is why different coloured signals can be sent down a single fibre, to multiply its capacity).

But at each end of the fibre, optical signals must be converted to and from the electrical signals that computers use to process information. The components that do such conversion are expensive. This does not matter in a network, where costs can be spread among many users. But this expense has kept optical data-links from being used inside personal computers and servers. That is now changing because computer systems are outrunning their electrical wiring. Peripheral devices like printers, hard drives and screens are getting more demanding; networks are running faster and, most importantly, the power of processors continues to increase exponentially. The so-called “interconnects” between all these components are struggling to keep up. It is in this area where a number of new optical alternatives are emerging from some of the biggest firms in the business.

Data in a flash

One of these new interconnects, called Light Peak, has been developed by Intel. It is being used to give ordinary PCs the ability to connect with other devices using high-speed optical cables at ten gigabits per second – 20 times faster than a standard USB cable. This means the cable could drive a high-definition display or transfer a movie in seconds. Light Peak, predicts Mario Paniccia, the head of Intel’s photonics lab, will make optical connections as pervasive as wireless ones – and drive demand for more powerful processors, which explains Intel's interest.

Intel did not have to invent anything new, but it did have to work out how to make small, cheap versions of the converters that turn electrical signals into light and vice versa. Having developed a simplified, low-cost chip to do the job, Intel also devised ways to assemble and test the components quickly, and signed up a group of suppliers to churn them out by the million, starting next year.

Hewlett-Packard's concern is keeping its servers competitive: their cabling is getting bulkier, and data centres are becoming much harder to cool and increasingly energy hungry. So it is developing an optical replacement for the interconnects in server "racks". Instead of optical fibre, HP is using waveguides – small strips of plastic with grooves on their highly reflective metallic walls. Again, using this technology to transmit light is not a new thing, but HP's researchers have managed to cut costs by making waveguides with an injection-moulding system similar to that used to mass-produce CDs.

Over at IBM, researchers are using optical interconnects to make supercomputers run faster. To speed up the flow of data, electrons need to be turned into photons "as close as possible to where the signal is processed", explains Bert Offrein of IBM Research. For this reason, it is mounting fibre-optic cables straight onto the chips that direct the traffic between a supercomputer's multiple processors.

The idea of using similar optical interconnects between a computer's various components is, based on existing technology, not something that is about to appear in humble home or office PCs any time soon. It is hard to make such components small and cheap enough to compete with copper wiring. But one technology that does show promise in making such connections is called "silicon photonics". It uses similar methods to those employed to manufacture processors and other types of integrated circuits.

Conveniently, silicon is not a bad material for making optical devices. Researchers at HP Labs recently managed to etch a pattern into a flat piece of silicon so that it could focus light "like a spoon", says Raymond Beausoleil of HP Labs. This effect, he says, could be used to improve lasers and replace expensive lenses in DVD players and other consumer products.

For its part, IBM has used silicon to develop a fast and extremely thin photodetector to convert optical signals into electrical ones. And Intel has come up with an entire kit of tiny optical devices made of silicon, which it hopes one day to combine on optical chips, such as waveguides and lasers. But one vital building block is missing from Intel's kit: an optical equivalent of the transistors that perform the logical operations at the heart of a computer.

This missing bit does not surprise David Miller of the Photonics Research Centre at Stanford University. Optical transistors, he says, will have a hard time competing with electrical ones, not least because there is no agreement over the best way to build them. Various techniques for making optical transistors regularly appear in laboratories. But using light to process information is tricky, requires exotic materials and lasers that demand more power than conventional transistors. Moreover, miniaturisation is not straightforward, not least because lasers cannot be made as small as transistors. So mass-produced optical processors remain far off. But at least the other bits are on the way.

Task 1

Find words that mean the following:
1. hard to find;
2. success;
3. to be limited;
4. to develop more quickly from smth else;
5. existing everywhere;
6. to make smth continue at its present level or amount.

Task 2

Say whether the following is true, false or is not mentioned
1. An experimental all-optical computer has recently been created;
2. The performance of an optkical computer could exceed that of the most powerful computers existing nowadays;
3. Having to convert optical signals into electrical ones prevents optical computer from being created;
4. Intel came up with a new way of converting electrical signals into optical ones and the other way round;
5. Optical interconnects may appear in every home or office within ten years;
6. Their size and the cost factor are the only obstacles in the way of creating optical computers;
7. Researchers have not come to a single opinion on methods of creating optical transistors;
8. Data processing with light will be more power hungry;
9. Silicon is not the best material to produce optical chips from.

5. WHAT VISIONS IN THE DARK OF LIGHT

Lene Vestergaard Hau made headlines by slowing light to below highway speed. Now the ringmaster of light can stop it, extinguish it and revive it – and thereby give quantum information a new look

By Marguerite Holloway

Lene Vestergaard Hau's favorite time of year is midsummer's eve, when the sky in her native Denmark turns a light metallic blue and the sun stays set for only a few hours. "It never really gets dark," she says one May morning in her sunny office at Harvard University. "You have these long, light nights. It is just a wonderful time of year. That is the thing I really miss here." Hau came to the U.S. for postdoctoral work two decades ago, vaulted into a new realm of physics, ignited another one, and has been here since, making the world think differently about the qualities of light.

The speed of light – 299,792,458 meters per second in a vacuum – "is an incomprehensibly high speed," Hau says. "If you could somehow tame that to a human level, it would be completely fascinating." That is exactly what the 47-year-old physicist has done: she has forced light to plod, pile up and squeeze into a tiny cage, stay docile in that cage and even vanish, only to reappear some distance off. Light slows all the time: photons passing through water decelerate to roughly 224,844,344 meters per second, and they stop and are obliterated when they hit opaque surfaces. But before Hau's work, light had never lagged to 17 meters per second and, in the same manner, been snuffed out and then revived intact.

Because photons travel far and fast without degrading, they have become the focus of research to develop quantum computers and improve optical communication. Hau's work is not directly applicable, because her experiments unfold in Bose-Einstein condensates – clusters of supercold atoms acting as one giant collective. Yet her research gets at the root of the challenge of using light to store and process information. By stopping the light, "you are storing a quantum bit. Conceptually, it is a new kind of memory unit," says Seth Lloyd, a quantum physicist at the Massachusetts Institute of Technology.

Hau, who won a MacArthur Fellowship in 2001, did not plan to be an experimental physicist. Her training was in the theoretical side, although in the 1980s, at home in Denmark and then at CERN near Geneva, she worked on condensed matter. "In doing that, I discovered that people had started to use new techniques of using lasers to cool atoms down to extremely cold temperatures," she recalls. In 1988 Hau traveled to the U.S. to meet researchers, give talks and satisfy a desire to "see if this country was really like the movies." Which, she decided, it was: big, with big cars and talkative, open people.

One of Hau's visits was to the Rowland Institute in Cambridge, Mass., a small nonprofit that joined Harvard five years ago. There she met physicists Michael Burns and Jene A. Golovchenko; both encouraged her to explore cold matter, even though neither worked in that emerging field. "I could have gone to a more established place, but it seemed that that would be too predictable," Hau says.

Hau set about designing a way to get a constant supply of sodium atoms in a vacuum. She then started cooling her sodium atoms toward absolute zero, and on midsummer's eve in 1997 she made "some really big, fat" Bose-Einstein condensates. This form of matter had been hypothesized but never created until three scientists – now Nobel laureates – managed to do so in 1995. Hau intended to use light to probe the properties of this new species when she decided to use the condensate to play with light instead. In 1999, in a now famous finding, Hau shone laser light on a condensate, causing photons to creep along inside it. "It was a very, very tricky experiment because it was just on the borderline of what was possible," she says.

What happens is this: The condensate contains sodium atoms held in place by a magnetic field and illuminated by a "coupling" laser that serves to make the condensate transparent to a specific frequency of light. When photons of that frequency, emitted in a short pulse by a "probe" laser, hit the condensate, they trigger a quantum dark state. This means the sodium atoms enter superposition – they are in two energy states simultaneously. As the photons encounter these atoms, they become entangled with them. The front edge of the light pulse slows, and the back edge catches up, compressing the light like a concertina into the 100-micron-thick condensate.

light had been slowed experimentally before by a factor of 165 (to 1,816,923 meters per second or so) using the transparency technique Hau employs. But "by observing light going 17 meters per second, it gave impetus to a worldwide effort in that direction," says Stephen E. Harris of Stanford University, who collaborated with Hau and first demonstrated electromagnetically induced transparency and slowed light with it in the early 1990s. Researchers have now slowed light in hot gases as well as in crystals and semiconductors at room temperature.

Slowing light led Hau to stopping and starting it. In 2001 she and her colleagues turned off the coupling laser and discovered that the light pulse in the condensate disappeared; its characteristic shape, amplitude and phase, however, were imprinted on the sodium atoms. When the coupling laser came back on, the incoming jolt of energy caused the altered sodium atoms to shift energy levels, in the process releasing a light pulse of the exact phase and amplitude as the one originally sent in by the probe laser. Light had come in with information, conveyed that information to matter and disappeared. Then matter had produced light with that same information.

"That is how we preserve information in the system. It is not some random thing that you have no control over," Hau says.

This year Hau and two members of her lab, Naomi S. Ginsberg and Sean R. Garner, took matters a step further by transmitting the light pulse's characteristics between two condensates. They sent a pulse from the probe laser into the first condensate, where, as expected, it slowed. Next they turned off the coupling laser. The light pulse from the probe disappeared, but not before it had communicated information about its amplitude and phase to the sodium atoms. These atoms also had momentum from the photonic collision, momentum that propelled them out of the first condensate, across a tiny gap and into the second condensate. Once the atoms – a matter copy of the extinguished light pulse – arrived, the coupling laser was turned back on; the atoms, eager to join the second condensate, shifted energy levels, releasing photons with the exact phase and amplitude of those that had entered the first condensate.

As Hau and Lloyd note, transferring light into matter and back again means that quantum information could be processed. "Basically, the probe light would carry quantum information over long distances in optical fibers," Hau explains. "Then if you want to do something to it, you read it into matter. We can use matter dynamics to change optical information." Light interactions in Bose-Einstein condensates have also produced unexpected phenomena – for example, tornadolike storms in the condensates sometimes act like billiard balls, bouncing off one another, and sometimes annihilate one another. "It is a total zoo," Hau says excitedly. "The experiments show much more detail than the calculations did."

Hau's many experiments kept her from the special blue of midsummer's eve again this year. But she brought Scandinavia to her new suite of labs: the walls are yellow and orange, and there is plenty of light wood. "Colors are very important," she says. "Colors and light, they are the way you feel how happy you are." Hau and poet Robert Frost seem of the same mind:

"The light was what it was all about
I would not go in till the light went out
It would not go out till I came in."

Task1

Find words which mean the following:
1. wonderful;
2. to become famous;
3. to disappear;
4. quiet;

5. to move slowly;
6. to start doing something with determination

Task 2

Answer the following questions:
1. What makes physicists so much interested in photons?
2. How can light be used to store information?
3. What was the difference between the 1990s experiments and the 2001 experiment?
4. How was the experiment developed?
5. What is its significance?

6. COULD LIGHT BEHAVE AS A SOLID? A NEW THEORY

Science Daily – “Solid light will help us build the technology of this century,” says Dr Andrew Greentree of the School of Physics at the University of Melbourne.

Quantum control: A potential design for a device which controls light. The block with the holes in it is a piece of diamond. The red spots are the particles of light ‘stuck’ in place, rather than roaming around freely. (Credit: Image courtesy of University of Melbourne)

Dr Greentree and colleagues Jared Cole and Professor Lloyd Hollenberg of the University of Melbourne with Dr Charles Tahan of the University of Cambridge made their ‘solid light’ breakthrough using tools more commonly used to study matter.

“Solid light photons repel each other as electrons do. This means we can control photons, opening the door to new kinds of faster computers,” says Dr Greentree. “Many real-world problems in quantum physics are too hard to solve with today’s computers. Our discovery shows how to replicate these hard problems in a system we can control and measure.”

He says photons of light do not normally interact with each other. In contrast, the electrons used by computers strongly repel each other.

The team has shown theoretically how to engineer a ‘phase transition’ in photons, leading them to change their state so that they do not interact with each other. “A phase transition occurs when something changes its state, for example when water becomes ice,” says team member Jared Cole. “Usually, photons flow freely, but in the right circumstances, they repel each other, and form a crystal.” He says phase transitions are very important in science and technology, but only the simplest phase transitions can be understood.

Dr Greentree says the solid light phase transition effect ties together two very different areas of physics, optics and condensed matter “to create a whole new way of thinking”. “It is very exciting for the University of Melbourne and its international collaborations to be leading the world in this new area,” he says.

Task 1

Find words meaning the following:
1. wandering
2. a great success;
3. to reproduce;
4. to happen;

5. to connect;
6. to force something similarly magnetized or charged away from each other;
7. the conditions that affect a situation, event

Task 2

Answer the following questions:
1. What do solid light photons and electrons have in common?
2. Why is this property so important?
3. Do photons and electrons behave in a similar way under ordinary conditions?
4. What is a phase transition?
5. What does it mean for photons?
6. This phenomenon is well understood, isn’t it?

7. LMDS: BROADBAND WIRELESS ACCESS

Ground-based wireless networks delivering the full range of broadband services can be deployed quickly and inexpensively.

by John Skoro

The past decade has seen explosive innovation by the telecommunications industry as it strives to satisfy a worldwide appetite for greater bandwidth. Several developments are fueling this growth – the proliferation of the Internet, increased dependence on data and a global trend toward deregulation of the industry.

Nowhere is the phenomenon more evident than in the quest to alleviate the local-loop bottleneck. This constriction occurs where local-area networks, which link devices within a building or a campus, join to wide-area networks, which criss-cross countries and hold the Internet together.

Advances in fiber technology have extended the capacity of wide-area networks to trillions of bits per second. Meanwhile local-area networks are evolving from 10 megabits per second (Mbps) to gigabits per second. The connections between these two domains have not kept pace, the vast majority of copper-wire circuits being limited to about the 1.5 Mbps rate of a so-called T1 line. The typical home user faces a more extreme case of the same affliction, with data crawling between computer and Internet about 30 times slower, through a modem and phone line operating at a mere 56 kilobits per second (kbps).

Of the variety of technologies developed for high-speed wireless access, local multipoint distribution service (LMDS) offers an ideal way to break through the local-access bottleneck. Like cell phone networks, LMDS is a wireless system but is designed to deliver data through the air at rates of up to 155 Mbps (typical cell phone voice calls use a mere 64 kbps, or 8 kbps in compressed digital systems). LMDS may be the key to bringing multimedia data to millions of customers worldwide. It supports voice connections, the Internet, videoconferencing, interactive gaming, video streaming and other high-speed data applications.

A major advantage of LMDS technology is that it can be deployed quickly and relatively inexpensively. New market entrants who do not have the luxury of an existing network, such as the copper wires or fiber of incumbent operators, can rapidly build an advanced wireless network and start competing. LMDS is also attractive to incumbent operators who need to complement or expand existing networks. For example, operators who are setting up a service primarily based on digital subscriber lines but who want their service to be universally available could use LMDS to fill in gaps in their coverage. And while cable modems are making inroads in the residential and home-office markets, the business market (where little to no cable network exists) remains a prime niche for LMDS.

The higher capacity of LMDS is possible because it operates in a large, previously unallocated expanse of the electromagnetic spectrum. In the U.S. the Federal Communications Commission has auctioned to LMDS operators a total bandwidth of about 1.3 gigahertz (GHz) in the “millimeter” waveband at frequencies of about 28 GHz. In other countries, depending on the local licensing regulations, broadband wireless systems operate at anywhere from 2 to 42 GHz. Canada, which is actively setting up systems around the country, has 3 GHz of spectrum set aside for local multipoint communications systems, as it is called there. Regular digital cell phone systems operate at about 0.8 GHz with a typical bandwidth allocation of 30 MHz or less.

How It Works

Sending digital signals of the required complexity at 28 GHz is made practical by recent improvements in the cost and performance of technologies such as digital signal processors, advanced modulation systems and gallium arsenide integrated circuits, which are cheaper and function much better than silicon chips at these high frequencies.

LMDS uses wireless cells that cover geographic areas typically from two to five kilometers in radius. Unlike a mobile phone, which a user can move from cell to cell, the transceiver of an LMDS customer has a fixed location and remains within a single cell. A common design puts the customers’ antennas on rooftops, to get a good line of sight to the hub transceiver.

The LMDS cell size is limited by “rain fade” – distortions of the signal caused by raindrops scattering and absorbing the millimeter waves by the same process that heats food in a microwave oven. Also, walls, hills and even leafy trees block, reflect and distort the signal, creating significant shadow areas for a single transmitter. Some operators have proposed serving each cell with several transmitters to increase coverage; most will have one transmitter per cell, sited to target as many users as possible. Of value to operators, in an industry with a high rate of turnover of customers, is the ability to pick up the hub equipment and move it to a different location, as market economics dictates – an impossibility with networks of telephone wires, television cable and optical fiber.

Most, if not all, LMDS systems send data using a technique called asynchronous transfer mode, which is used extensively in wide-area networks and allows a mixture of data types to be interleaved. Thus, a high-quality voice service can run concurrently over the same data stream as Internet, data and video applications. In summary, LMDS will be a versatile, cost-effective option for both providers and users of broadband services, with the rapid and inexpensive deployment being particularly attractive to the providers.

Task 1

Say whether the following is true, false or is not mentioned.

1. LMDS was specially developed to cope with the problem of a local loop bottleneck.
2. The problem is caused by a mismatch between local area networks and global networks.
3. LMDS is the best way to overcome the problem of a local loop bottleneck.
4. It is intended to send multimedia data over an optical fiber at great rates.
5. Its great advantages are mobility and low cost.
6. In the future LMDS will be able to successfully compete with and eventually replace existing cable networks.
7. Since it operates at great frequencies, LMDS has a great capacity.
8. Its capacity can easily be increased.
9. The quality of the LMDS signal depends on weather conditions and obstacles in the way.

Task 2

Answer the following questions:

1. What is a local loop bottleneck?
2. How can the problem be coped with?
3. What are the LMDS specifications?
4. How can its large capacity be explained?
5. Why cannot the cell be made as large as we please?
6. How can distortion problems be solved?
7. What is the main principle of the asynchronous transfer mode?

Task 3

Find words which mean the following:

1. to develop
2. to make great efforts to achieve something
3. to change or increase as fast as something else
4. able to be used or obtained
5. happening at the same time

8. THIRD-GENERATION GAP

By Leander Kahney

Just wait until cell phone networks go high-speed. It will start to happen later this year, as carriers in Japan begin to deploy so-called 3G, or third-generation wireless cell phone systems. Spreading from east to west, the nimble networks should arrive in Europe in 2002 and the U.S. in 2003. Unlike the previous two generations of cellular networks, 3G systems have been designed from the get-go to carry data as well as voice. Carriers promise downloads approaching 2.4 megabits per second (Mbps)-twice as fast as wired broadband services, and fast enough to bombard cell phones, handhelds and laptops with video, music and games.

Or so they say. But there is a growing chorus warning that 3G will not be all it’s cracked up to be.

3G is not a single standard or technology but an umbrella term for a variety of approaches to bringing high-speed Internet services to cell phone networks. In most cases, 3G will come from updates and upgrades to current systems, which differ from continent to continent and from country to country. Most 3G networks will start off as hybrids, with new capabilities added gradually as demand dictates.

The result is an alphabet soup worthy of a convocation of rocket scientists. In general, Europe and Asia will convert from GSM (Global Standard for Mobile communications), whose widespread adoption has given them the lead in wireless technology, to W-CDMA (Wideband Code Division Multiple Access). In North America, CDMA (Code Division Multiple Access) networks, such as Sprint’s and GTE’s, will also migrate to W-CDMA. But TDMA (Time Division Multiple Access) systems, such as AT&T’s and Southwestern Bell’s, plan to go to EDGE (Enhanced Data rates for Global Evolution).

These systems are still mostly in an experimental or testing stage, and each has its advantages and disadvantages. EDGE requires relatively minor infrastructure upgrades, but its theoretical maximum data rate of 384 kilobits per second (kbps) pales when compared with W-CDMA’s much faster 2 Mbps.

W-CDMA and CDMA are based on a technology known as spread spectrum. Older cellular technologies such as GSM and TDMA use a variant of the approach taken by ordinary radio stations – namely, they divide the radio spectrum into narrow frequency bands. To add capacity, these networks can interleave several phone calls on each frequency channel, but there is a tight limit to how many users can share a channel before the signal quality suffers. CDMA, on the other hand, assigns each phone call a particular code. Multiple radio signals can then share a fairly wide range of radio frequencies. Each phone will pick up the transmissions intended for it by watching for its code. In some implementations of spread spectrum, the transmitter and receiver hopscotch among frequencies in a prearranged sequence [see "Spread-Spectrum Radio," by David R. Hughes and Dewayne Hendricks; Scientific American, April 1998].

Although spread-spectrum systems have their inefficiencies – with all the overhead to determine which messages are going to which phone, they tend to use a lot more bandwidth than the signals alone require – they are very tolerant of noise and are difficult to intercept or interfere with. CDMA uses channels 1.25 megahertz (MHz) wide in the 800-MHz or 1.9-gigahertz (Ghz) bands. W-CDMA channels are 5, 10, 15 or 20 MHz wide in several bands located around 2 GHz, which allows for faster data rates and more users.

Yet these are not the only available technologies – or even, critics say, the best ones. One of the most vocal naysayers is Martin Cooper, who is widely credited with inventing the cell phone for Motorola in the early 1970s. The 3G networks, he says, will offer just over 1 Mbps when all the overhead is taken into account. But that's not 1 Mbps per user: the bandwidth will be shared among everyone in a particular cell (the geographical area covered by a single cell tower), which could be dozens of people at a time on each channel. Cooper says users should expect 64 kbps from 3G networks at best, a privilege for which they will pay a handsome premium. Although quite an improvement on current wireless networks, it is only marginally faster than an ordinary modem and hardly enough to justify all the futuristic claims made for the networks.

For Cooper, 3G is a baby step toward real high-speed, inexpensive wireless communications. He is now at ArrayComm, a San Jose, Calif., start-up working on "smart antennas," which, he claims, could provide 1 Mbps for each of up to 40 concurrent users. The technology makes better use of the arrays of antennas found in cellular base stations. As you may have noticed when driving by a cell tower, each station contains a forest of up to a dozen antennas. Currently they are used to broadcast omnidirectionally – that is, with equal strength in all directions.

But many communications and radar systems have long used similar arrays to aim their signals in particular directions. The transmissions from individual antennas interact with one another, preventing the signals from going in some directions and amplifying them in others. Cooper proposes retrofitting cellular base stations to the same end.

His system is based on digital signal processors originally developed by the U.S. military for spying on foreign radio broadcasts. Such signal processors, when attached to an antenna array, can beam radio signals precisely at individual users. As each user moves around, the smart antennas track them. The result is a kind of cloud of radio signals that follows each user around like the cloud of dust around Pigpen.

The system can reuse the same radio frequencies for different users in the same vicinity, without worrying that the transmissions will interfere with one another. The result is very efficient use of the carrier’s spectrum, which affords the high data rates.

The antennas are already in place, and most cellular base stations have signal processors with the necessary computational power. So in most cases a software upgrade is all that is required to turn them into smart antennas. The drawback is that high data rates come at the expense of movement. Although the system is able to track a walking subject, it currently can’t keep pace with a fast-moving vehicle. ArrayComm plans to begin wide-scale tests soon and has teamed up with Sony to deliver video, music and games over the airwaves in San Diego.

A radically different approach is being taken by inventor Larry W. Fullerton, who has spent the past two decades working in obscurity on a potentially revolutionary technology known as UWB (ultrawideband). Most radio transmissions have two components: a carrier wave and a signal. The carrier wave is the vehicle; it is the frequency to which you tune a radio. The signal is the passenger; it comes from a microphone, TV camera or Internet connection and is imprinted onto the carrier wave in a process known as modulation. The most common style of modulation, FM (frequency modulation), causes the carrier to spread out by an amount roughly equal to the data rate of the signal. A 10,000-bps message, for instance, causes the carrier to “smear” by 10 kHz on each side. This is why radio stations have to be spaced apart in frequency.

Spread-spectrum radio, used in the most advanced cell networks today, essentially switches among many different carriers for a given transmission. But UWB, first devised in the 1960s, dispenses with the carrier altogether. It is pure signal. In essence, a switch attached to the antenna turns on and off, which produces a pulse of electromagnetic energy – rather like the pop you hear on the radio when turning on a lamp. In Fullerton’s systems, the pulses last less than a billionth of a second each and occur up to 40 million times per second. Like an ultrafast Morse code, the pulses occur in a very particular pattern, which can encode the desired information.

One implication of UWB sounds utterly crazy: rather than take up a small slice of the radio spectrum, as other technologies do, it uses the whole thing. Typically the pulses carry energy from 1 to 3 GHz. Fortunately, that doesn’t lock out other radio systems. To most radio receivers, the UWB signals sound like random static and can be filtered out as long as their power remains low. Only receivers that know the pattern of pulses can recognize and decode the signals. Different UWB transmitters can use different patterns, allowing many to operate at once without interfering with one another.

Fullerton is now chief technology officer of Time Domain, a Huntsville, Ala., firm created to commercialize the technology. The firm hopes to push the data rates even higher. “Our engineers – with a straight face – tell me we can get a gigabit per second,” says Ralph Petroff, the company’s president. Several other firms, such as Multispectral Solutions in Gaithersburg, Md., have also been working on the technology. Until this spring the Federal Communications Commission (FCC) had licensed UWB only for limited experiments, but in May it gave the go-ahead for much wider tests.

UWB has a wide variety of potential uses, from personal radar systems for detecting collisions to imaging devices that can see through walls. But will it ever provide high-bandwidth wireless communication? To keep the signals from interfering with other radio devices, UWB broadcasts at extraordinarily low power-50 millionths of a watt. Trouble is, low power means low range – just a few meters. The more power, the farther it could reach, but the greater the chance it would interfere with radios, televisions and Global Positioning Satellite receivers. Petroff says UWB will initially be confined to indoor local area networks, a kind of Bluetooth on steroids, but may one day be used for neighborhoodwide networks.

“I think there’s going to be some kind of power restriction from the FCC that will restrict its range,” comments Bob Scholtz, a professor of electrical engineering at the University of Southern California. “But we don’t know what that will be. It could be hundreds of yards.”

Yet another approach – one that has been around in one form or another since the 1950s – is based on a communications technique known as multiplexing, which involves the transmission of more than one signal over the same channel. Multiplexing is commonly used in fiber optics, in which a big packet of data is chopped into smaller pieces, transmitted simultaneously on different wavelengths of light and stitched back together at the other end. Exactly the same principle applies in a wireless system, except that the wavelengths used are in the radio part of the electromagnetic spectrum.

To date, wireless multiplexing hasn’t been exploited for cellular systems because digital signal processors fast enough to track and combine the different signals have not been available. That may change soon. A Calgary, Alberta – based company called Wi-LAN holds a number of key patents for a multiplexing technology known as wideband orthogonal frequency division multiplexing, or W-OFDM.

According to the company’s CEO, Hatim Zaghloul, W-OFDM can deliver very high data rates across a limited range of radio spectrum – approximately 10 MHz in the unlicensed industrial-scientific-medical (ISM) bands at 900 MHz, 2.4 GHz and 5

GHz. The 10 MHz is divided into 10 evenly spaced channels, each of which can carry 1 Mbps of data.

So what, you might ask? After all, those 10 MHz could just be lumped into a single 10-Mbps channel. Multiplexing can’t deliver something for nothing: it may divide a high-speed data stream into several low-speed data streams, but the total capacity of the radio spectrum, which is fixed by the laws of physics, must remain the same.

The key is that fast signals are more easily degraded by noise, interference and so-called multipath effects, which are caused by radio signals’ bouncing off buildings or other landmarks. Slow signals, on the other hand, can slink through the static. By subdividing the spectrum, then, W-OFDM uses it more efficiently.

In one configuration, Wi-LAN has achieved 32 Mbps. In tests conducted earlier this year, technicians broadcast a stream of video to a car traveling at 70 miles per hour. Zaghloul says that he expects a whopping 155 Mbps by the end of next year as improved signal processors allow for more channels. The technology could be deployed in fixed wireless systems early next year and in mobile systems by 2003. The downside is that W-OFDM would require significant reworking of current cellular networks. Its adoption may have to wait until carriers look past 3G systems to 4G.

Because so many technologies-spread spectrum, antenna arrays, UWB, multiplexing and others-are in the works, many analysts are coming to realize that the biggest obstacle to fast wireless communications is not the engineering but the business model. What resources are carriers willing to put into their systems? What trade-offs will they make between the available bandwidth and the number of users forced to share it? “Deployment is the big issue,” says Craig Mathias, an affiliate analyst with market research firm MobileInsights. “3G depends on the carriers. If they want to deliver high-speed data networks, they’ll do it. But the business today is voice. The big question is the business plan, not the technology.”

Cooper says that today’s wireless industry is dominated by telecom monopolies that think in terms of a one-size-fits-all network. Instead, he says, he would like to see a multitude of different networks for different purposes. He predicts that nationwide voice networks will coexist with local data networks, and that low-cost, low-speed networks will rub shoulders with pricier high-speed ones. As for speed, Cooper says that wireless networks will eventually deliver the performance of wired ones.

In many ways, it’s only an accident of history that we have wired, rather than unwired, telecommunications. If Guglielmo Marconi and Nikola Tesla had been a few years ahead of Alexander Graham Bell, instead of the other way around, we might have had a very different telecom landscape today

Part 1 (up to ‘digital signal processors’)

Task 1

Find words which mean the following:
1. from the beginning;
2. to praise;
3. advantage;
4. to mix (signals) by alternating between them;
5. agreed upon or assigned in advance;
6. only just, slightly;
7. at the cost of;
8. to move at the same speed as;
9. absolutely seriously;
10. to give the green light, permit;
11. to limit.

Task 2

Say whether the following is true, false or is not mentioned.
1. 3g systems are based on previous standards.
2. They are intended to combine mobile phones and high speed Internet access.
3. They have used a number of approaches to form a new unified standard.
4. All systems use spread spectrum technologies.
5. Spread spectrum technologies are widely used in military applications, e.g. radars.
6. In CDMA each phone gets a special combination of digits or signatures allowing radio signals to use a wide frequency range.
7. Spread spectrum systems produce a pseudo white noise.
8. Spread spectrum systems are far more effective than all the rest.
9. A faster and more efficient way of communication are so called smart antennas.
10. Smart antennas are supposed to track any moving object but are unable to track an object moving at a high speed.

Part 2 (from ‘To date wireless multiplexing… ‘ up to the end)

Task 1

Say whether the following is true, false or is not mentioned:
1. UWB uses an ultrafast Morse code.

2. This technology is suitable for local networks, only.
3. UWB does not interfere with any other electronic equipment.
4. It is impossible to intercept or decode a UWB signal.
5. To send a signal a spread spectrum radio is used which chooses among a number of different channels.
6. UWB is ideal for spying or secret surveillance and allows creating devices which can see through walls.
7. In multiplexing we can send a lot of signals over the same channels.
8. This principle hasn’t been used in mobile phones due to technical problems.
9. At present there are no techniques allowing us to use wireless multiplexing.

Task 2

Answer the following questions:
1. What is the main drawback of UWB?
2. What is multiplexing?
3. Why should we use it if we can send the same amount of data over a single 10mb/s channel?
4. What technology was used to transmit a video stream to a fast moving object?
5. What is the main drawback of W-OFDM?
6. The text mentions 32Mb/s and 155Mb/s. Are such data rates possible with 3g nowadays? Is live video streaming possible?

9. COMPUTERS: ADDING CARBON GIVES IRON – PLATINUM NANOCRYSTALS IDEAL OPTICAL PROPERTIES FOR HEAT-ASSISTED MAGNETIC RECORDING

The disk drive in a computer works by using a magnetic field to change the physical properties of a tiny volume of a magnetically susceptible material. Current research aims to develop novel materials and technologies that can maximize storage capacity by focusing data into the smallest possible volume.

The disk drive in a computer works by using a magnetic field to change the physical properties of a tiny volume of a magnetically susceptible material. Current research aims to develop novel materials and technologies that can maximize storage capacity by focusing data into the smallest possible volume.

Now, Zhanhong Cen and co-workers at the A*STAR Data Storage Institute in Singapore have experimentally and theoretically investigated the properties of iron-platinum (FePt) nanocrystals for use in ultrahigh-density magnetic recording media. They show that, as well as having the appropriate magnetic characteristics, the optical response of FePt is suitable for high-performance data-storage applications and that the use of pulses of laser light improves the magnetic recording process1.

"Decreasing the size of magnetic particles makes the magnetic information become thermally unstable due to an effect called superparamagnetism," explains Cen. "FePt nanoparticles are very promising, because for these nanoparticles, superparamagnetism is suppressed at room temperature."

But FePt nanoparticles also have a drawback -- the magnetic field required for writing data is much higher than that produced by present disk drives. While the magnetic-field intensity necessary for a change of state could potentially be reduced by locally heating the material with a pulse of light – a process called heat-assisted magnetic recording, little was known about the optical response of FePt until now.

Cen and the team created thin-film samples using a process known as sputtering, which involves firing a beam of particles at a FePt alloy to release iron and platinum atoms. The atoms land on a glass substrate covered with a layer of magnesium oxide where they form crystals. The team sputtered carbon at the same time to form a single layer of FePt nanocrystals 15 nanometers in diameter and 9.1 nanometers tall embedded in a film of carbon.

For comparison, the team also created a nanocrystal sample without carbon and probed the refractive index and absorption of the two samples with both visible and near-infrared light. The researchers used these values in a computer model to simulate the performance of the material in a heat-assisted magnetic recording device. The sample doped with carbon came out on top.

"Our simulations show that introducing carbon into a FePt nanocomposite can improve optical performance," says Cen. "Ultimately, a FePt-carbon recording medium will perform better than current storage options, because it will use a smaller optical spot on the recording media and enable more energy-efficient writing and reading of data."

Task 1

Find words which mean the following:

1. very small;
2. likely to be affected by a particular problem;
3. to make better;
4. disadvantage;
5. to include;
6. to prevent or inhibit.

Task 2

Say whether the following is true, false or is not mentioned.

1. The optical properties of iron-platinum make it good for a high capacity storage device.
2. In contrast to magnetic particles nanoparticles do not need low temperatures.
3. Superparamagnetism is suppressed for nanoparticles as they are zapped with high intensity laser pulses.
4. Iron-platinum nanoparticles are ideal for creating high capacity disk drives.
5. Nanocrystal particles reveal the same optical properties whether they have carbon or not.
6. Since iron- platinum carbon nanoparticles are more efficient, it is possible to read and write more data, more densely.

Task 3

Answer the following questions.

1. What makes the disk drive in a computer tick?
2. Why are nanocrystals suitable for high density storage?
3. How does superparamagnetism affect the magnetic information?
4. What makes nanoparticles different?
5. How does sputtering work?
6. Have iron-platinum nanoparticles any disadvantages?
7. How can the drawbacks cope with?
8. What are better FePt nanoparticles’ properties due to?

10. A VERTICAL LEAP FOR MICROCHIPS

Engineers have discovered a way to pack more computing power into microcircuits: build them vertically as well as horizontally.

By Thomas H. Lee

The city of San Francisco stretches over 45 square miles – about twice the area of the island of Manhattan. Yet the economic output of Manhattan dwarfs that of San Francisco. A principal reason for the disparity is that offices in earthquake-prone California tend to spread their workers and machines close to ground level, whereas businesses in New York are stacked vertically into the skies. By building upward rather than outward, developers increase not only the value of their real estate but also the working power of the city as a whole.

An analogous strategy applied to the microscopic world of computer chips could rejuvenate a semiconductor industry that has recently begun to show signs of senescence. Surprisingly, of the more than 100 quadrillion transistors that Intel co-founder Gordon E. Moore estimates have been produced to date, nearly every one has been built on the “ground level,” directly on the surface of silicon crystals. Engineers have accomplished a fantastically regular doubling of transistor density per microchip – we call it Moore’s Law in the industry – simply by expanding the area of each chip and shrinking the size of each transistor. This is like building only shopping malls and no skyscrapers.

This year 3-D memory circuits will hit the market, just the first of a new generation of dense, inexpensive chips that promise to replace photographic film and audiotape.

That is about to change. For one thing, physicists tell us that Moore’s Law will end when the gates that control the flow of information inside a chip become as small as the wavelength of an electron (on the order of 10 nanometers in silicon), because transistors then cease to “transist.” And many intimidating technical obstacles loom between the current state of the art and that fundamental limit. The trajectory of progress has already begun to droop.

Fortunately, I and other engineers have recently found a way to skirt some of those obstacles, to give Moore’s Law a new breath of life and even to accelerate the delivery of more computing power for less cost. We have shown that it is feasible to make chips that contain vertical microcircuits using the same semiconductor foundries, the same standard materials and similar techniques to those used to manufacture conventional computer chips.

Such “three-dimensional” chips are now being commercialized by Matrix Semiconductor, a company I co-founded in 1998 in Santa Clara, Calif., with computer scientist P. Michael Farmwald and chip design expert Mark C. Johnson.

Sometime in the first half of 2002, 3-D memory circuits will hit the market. They will be just the first of a new generation of dense, inexpensive chips that promise to make digital recording media both cheap and convenient enough to replace photographic film and audiotape. In laboratories at Stanford University and Matrix, we have also created prototype devices that incorporate vertical logic circuits. There seems to be good reason to expect that even for microprocessors, the sky is the limit.

The Fences of Flatland

Today's state-of-the-art microcircuits are not entirely two-dimensional. Intel's Pentium 4 processor, for example, boasts seven layers of wiring, embedded within patterns of insulating material. It is only on the bottom layer of pure silicon, however, that the active semiconducting regions lie.

LAYERS OF POLYSILICON that form the honeycomb of memory cells(left) are interconnected by "vias" (vertical columns at right). These are connected by tungsten wires (bright structures).

So far the industry has managed to sustain Moore's Law largely by improving the way it uses that silicon wafer. Materials scientists have invented ways to grow giant crystals of silicon 30 centimeters in diameter that contain less than one part per billion of impurities. Clean-room robots shoot carefully metered doses of ions into wafers cut from these crystals. A process called photolithography defines the ion-activated regions with patterns of light and acid etching to make transistors. To cram more transistors onto one wafer requires light of ever shorter wavelength. Mercury vapor lamps have been replaced by deep-ultraviolet excimer lasers that inscribe 130-nanometer features and can put a billion transistors on a chip. Further improvement should push that limit to 65 nanometers and perhaps 16 billion transistors.

The road beyond that point may be rough, however. Extreme ultraviolet lithography systems that use even shorter wavelengths are just now beginning to function in the laboratory. They still pose many significant problems [see "Getting More from Moore's," by Gary Stix; Scientific American, April 2001].

Moore's Law – the steady growth in silicon-based microchip complexity on which the information technology industry depends – is approaching fundamental physical limits. Switching from silicon to new kinds of semiconductors would be enormously expensive.

Engineers recently have found a way to extend and perhaps accelerate Moore's Law significantly. They have designed and mass-produced multilayered chips in which the semiconducting parts of circuits are no longer confined to a single plane but extend vertically as well.

The first products incorporating such 3-D microchips – memory cards cheap enough to use as digital film and audio-recording media – are scheduled to appear later this year.

If history is any guide, engineers will probably clear these hurdles; the economic incentive to do so is huge. But as the number of obstacles increases, the pace of progress may slow considerably. The official “road map” published by the Semiconductor Industry Association projects that chips will grow 4 to 5 percent a year in area; historically, area has grown about 15 percent a year. The periodic 30 percent reduction in minimum feature size is probably now going to occur every three years instead of every two. Even at this slower pace, Moore’s Law will most likely hit fundamental limits sometime between 2010 and 2020.

One important factor has remained roughly constant: the cost of semiconductor real estate, at about $1 billion per acre of processed silicon. So why haven’t silicon developers taken the seemingly obvious step of building upward? The simplest reason is that transistors are fastest and most reliable only when formed from the perfectly aligned atoms of a wafer cut from a single crystal of silicon.

Once we coat that semiconducting wafer with an insulating oxide or metal wires, there is no known way to recover the underlying crystalline pattern – it’s like trying to match the pattern of a parquet floor after it has been covered with carpet. Silicon deposited onto a noncrystalline surface tends to be completely disordered and amorphous. With apppropriate heat treatment, we can encourage the silicon to form minuscule islands (“grains”) of single crystals, but the ordered lines of atoms collide abruptly at odd angles at the boundaries between grains. Contaminants can pile up at these barriers and short out any transistor or memory cell caught in the middle. For many years, such amorphous and polysilicon (short for polycrystalline silicon) devices were so poor that no one seriously considered them for anything more sophisticated than solar cells.

In the early 1980s, however, premature worries that Moore’s Law was about to fail stimulated a flurry of attempts to make 3-D microcircuits in which the transistors spanned vertical towers – rather than horizontal bridges – of silicon. James F. Gibbons and others at Stanford used laser beams to improve the quality of silicon films deposited onto nonsilicon substrates. Others tried stacking conventional 2-D chips on top of one another. Regrettably, the former approach was too slow and the latter was too expensive to be economically competitive. Traditional chipmaking stayed on track, and engineers stopped thinking much about vertical circuits.

A New Use for Old Tools

In 1997 farmwald and I started exploring 3-D chips again and realized that two key enabling technologies, developed for other purposes, made 3-D circuits truly practical for the first time. One was a technique to lay down polysilicon so that each island of a single crystal is large enough to encompass many memory cells or transistors. The second advance was a way to flatten each coat of new material so that the chips don’t rise unevenly like towers built by drunken bricklayers.

We can thank the flat-panel-display industry for the first breakthrough. Its engineers figured out how to make millions of transistors from a thin film spread over a large, amorphous substrate (glass, in their case; other materials in ours). Thin-film transistors now populate the display panels of virtually every laptop computer. Part of the secret is to deposit the silicon at about 400 degrees Celsius as an extremely smooth (though amorphous) film, then to cook the entire wafer uniformly above about 500 degrees C for a few minutes. This converts the film to polysilicon with regular crystalline regions of a micron or more in diameter. Although LCD panels require only a single layer of transistors, the same machines that make the panels can also manufacture multilayer devices.

The second key enabling advance, called chemical-mechanical polishing (or CMP), emerged from IBM’s research labs in the late 1980s. Back then, chip designers considered it risky to add two or three layers of metal on top of the silicon wafer because each new layer added hills and valleys that made it difficult to keep photolithographic patterns in focus.

To eliminate the bumps in each layer, process technologists adapted a trick that lens makers use to polish mirrors. The basic technique was used on all Intel 80486 processors: after each coating of silicon, metal or insulating oxide is added, the wafer is placed facedown on a pad. Spindles then rotate the pad and wafer in opposite directions while a slurry of abrasives and reactive alkaline chemicals passes in between. After mere minutes of polishing, the wafer is flat to within 50 nanometers, an ideal substrate for further processing. With advances in CMP machines, seven and eight layers of metal have become common in microchip designs; patience seems to be the main limiting factor in adding still more layers.

Building directly on these 2-D technologies, we have made 3-D circuits by coating standard silicon wafers with many successive layers of polysilicon (as well as insulating and metallic layers), polishing the surface flat after each step. Although electrons do not move quite as easily in polysilicon as they do in the single-crystal kind, research has produced 3-D transistors with 90 to 95 percent of the electron mobility seen in their 2-D counterparts.

Stacking devices vertically offers a way around some of the weighty obstacles that threaten to derail Moore’s Law. As shopping-mall-style chips continue to sprawl outward, for example, it becomes increasingly hard to keep the photolithographic image in focus at the edges. And the relatively long wires that connect far-flung sections of conventional microprocessors cause delays that reduce performance and complicate design.

Ever shrinking circuits pose other problems. Transistors depend critically on a thin insulating layer below the control electrode. In the most advanced 2-D chips, this layer of silicon dioxide insulation measures just three nanometers – about two dozen atoms – in thickness. From transistor to transistor, that thickness must not vary by more than one or two atoms. The industry routinely meets this challenge, because it is much easier to grow superthin films than it is to etch supernarrow channels. But there may be no practical way to make these insulating layers much thinner, because current flow by quantum tunneling makes them progressively worse insulators. It's likely that some other material will soon have to replace silicon dioxide, but toolmakers have yet to agree on what that material will be.

Vertical electronics can reduce manufacturing costs 10-fold or more, and the density of 3-D devices should increase at least as fast as Moore's Law as we add layers.

There have been many novel chip designs proposed to address these problems. Most depend on replacing silicon altogether with various exotic materials, such as organic polymers, carbon fullerenes, copper compounds, ferroelectrics or magnetic alloys. But to abandon silicon is to squander an enormously valuable foundation of knowledge constructed over 50 years with some $100 billion worth of investment. The 3-D electronic design process, in contrast, introduces no new atoms and leverages the huge industry investment in thin-film and CMP equipment. Because it is so expensive to produce and process ultrapure silicon ingots, the cost of silicon is largely proportional to the area (not the volume) consumed. So vertical electronics can reduce manufacturing costs 10-fold or more compared with traditional chips. And the density of 3-D devices should increase at least as fast as Moore's Law as we add more and more layers.'

Digital Film and Beyond

Traditionally, semiconductor companies have worked the bugs out of new fabrication processes by making memory devices before attempting to mass-produce more complicated chips such as logic circuits. Memories are vast arrays of fundamentally simple cells, so there are fewer skills to master and fewer problems to solve.

That is the approach we at Matrix will take later this year as we introduce a 3-D memory chip in which the cells are stacked eight high [see illustration below]. Unlike the RAM memories used in PCs, these chips use exceedingly simple memory cells that make them more like film, indelible once written. They are intended to be a low-cost medium for digital photography and audio. With 512 million memory cells, this first vertical microchip has enough capacity to store more than an hour of high-quality audio (through data compression) and a few hundred photographs (each comprising about one million pixels). The capacity will rise, and the unit cost will fall, over time. We have already proved that 12-cell-high devices are feasible, and 16-layer chips seem well within reach.

We have also demonstrated much more complex 3-D microcircuits in the laboratory, including static RAM, logic gates and even erasable EPROM memories. Although they are in very early stages of development, these basic building blocks are all that is needed to recast any planar circuit – including dynamic RAM, nonvolatile memories, wireless transceivers, and microprocessors – in 3-D form. Stood on end, the transistors in such circuits could be quite tiny because their channels will be made from thin films that are 10 times as precise as channels defined by ultraviolet light.

As with all engineering advances, this new manufacturing technique has limitations and trade-offs. Some fraction of memory cells or transistors in a vertical microcircuit will happen to straddle a boundary between polysilicon grains and will possibly fail as a result. We will have to use error detection and correction routines, like those used with audio CDs, and find ways to route signals around defective paths. The strategies of fault-tolerant computing, though well known, have generally not been built into microchips themselves. Such techniques are unnecessary and too cumbersome for application in most planar contexts, but the cost reductions afforded by 3-D processing fortuitously make the remedial technology economically feasible precisely when it becomes necessary.

Speed is another trade-off. Modern thin-film transistors typically perform at about half the speed of monocrystalline devices, although the difference is smaller when you compare entire circuits, because components packed in three dimensions need considerably shorter wires. Numerous researchers are investigating ways to close that gap further.

Beyond those special considerations, 3-D chips face essentially the same challenges as do conventional planar electronics – certain problems just appear sooner because of the effective acceleration of Moore's Law. Heat may be the most acute issue for dense 3-D devices because of their smaller surface area. The power density of a modern microprocessor already exceeds that of the burner on a typical stove. Ineffectiveness of current strategies for dissipating all that heat, such as reducing voltages or selectively activating only parts of a circuit, may limit the performance of dense 3-D circuits unless more advanced cooling technology is used. Fortunately, the newest microrefrigerators can now remove 200 watts per square millimeter while consuming only about one watt. Thermal limits are thus not yet fundamental impediments.

There is certainly lots of room for improvement. The fluid-cooled human brain, whose dimensions considerably exceed those of any 3-D circuit currently contemplated, dissipates a mere 25 watts; a 2.2-square-centimeter Pentium 4 microprocessor, in contrast, consumes about 80 watts. Although we cannot rule out the possibility that the inability to solve the heat problem may ultimately impose harsh limits on what 3-D circuits can do, history suggests that the strong economic incentives at play will eventually spark creative solutions.

Enabling Moore’s Law to continue even a few years longer than it otherwise would have will have far-reaching consequences. For 30 years, chip manufacturers have striven constantly to print ever smaller structures within a single plane. It seems inevitable that in the future we will scale microcircuits vertically as well as horizontally. The technology is both possible and practical, and the benefits are far too compelling to ignore.

Part 1 (up to ‘New use for old tools’)

Task 1

Find information for or against the following:
1. Moore’s law will cease to operate beyond a certain point.
2. The centre of New York produces as much as the whole of the Californian capital.
3. One way of overcoming limitations connected with Moore’s law is to create a vertical chip.
4. It is impossible to put over 16bln transistors on a chip since it is a limit imposed by fundamental physics.
5. The author is sure that engineers will cope with all difficulties.
6. The first attempts to create a 3d chip failed as the process was either too time consuming or too costly.
7. Atoms orientation in silicon is the most important factor to affect the transistor performance.

Task 2

Answer the following questions:
1. Why does the author compare the output of Manhattan with that of San Francisco?
2. Are scientists united in their opinion about Moor’s law?
3. Why can’t we call Pentium4 a 3d chip?
4. How are transistors made?
5. What is the relation between light wavelength and the number of transistors we can put one chip?

Part 2 (from ‘New use for old tools’ up to the end)

Task 1

Find information for or against the following:
1. 3d chips are based on cutting edge technologies.
2. The second technology appeared due to the fear of using multilayer structures.
3. Creating perfect mirrors gave rise to the idea of using the same technique to polish the silicon wafer.
4. There is no difference in speed between 3d chips and conventional chips.
5. 3d chips could prolong Moore’s law life.
6. The laws of physics prevent us from making superthin insulators.
7. Some transistors in 3d chips may find themselves in the wrong position.
8. A modern chip emits as much heat as a microwave.
9. Since the heat problem is due to fundamental laws of physics, the only way to cope with it is impose strict limitations on 3d chips.

Task 2

Answer the following questions:
1. What were the stages of creating 3d chips?
2. How was each layer flattened?
3. What prevents us from adding more and more layers?
4. What’s wrong with conventional chips?
5. Why can’t we make insulation layers in 2d chips as thin as we please?
6. Wouldn’t it be better to give up silicon completely and use some other materials? Why? Why not?
7. What’s the difference between RAM memories for PCs and 3d memory chips?
8. What’s the greatest problem of 3d chips?

11. INTRODUCING THE VACUUM TRANSISTOR: A DEVICE MADE OF NOTHING

This curious mash-up of vacuum tube and MOSFET could one day replace traditional silicon

By Jin-Woo Han & Meyya Meyyappan

In September 1976, in the midst of the Cold War, Victor Ivanovich Belenko, a disgruntled Soviet pilot, veered off course from a training flight over Siberia in his MiG-25 Foxbat, flew low and fast across the Sea of Japan, and landed the plane at a civilian airport in Hokkaido with just 30 seconds of fuel remaining. His dramatic defection was a boon for U.S. military analysts, who for the first time had an opportunity to examine up close this high-speed Soviet fighter, which they had thought to be one of the world's most capable aircraft. What they discovered astonished them.

For one thing, the airframe was more crudely built than those of contemporary U.S. fighters, being made mostly of steel rather than titanium. What's more, they found the plane's avionics bays to be filled with equipment based on vacuum tubes rather than transistors. The obvious conclusion, previous fears aside, was that even the Soviet Union's most cutting-edge technology lagged laughably behind the West's.

After all, in the United States vacuum tubes had given way to smaller and less power-hungry solid-state devices two decades earlier, not long after William Shockley, John Bardeen, and Walter Brattain cobbled together the first transistor at Bell Laboratories in 1947. By the mid-1970s, the only vacuum tubes you could find in Western electronics were hidden away in certain kinds of specialized equipment – not counting the ubiquitous picture tubes of television sets. Today even those are gone, and outside of a few niches, vacuum tubes are an extinct technology. So it might come as a surprise to learn that some very modest changes to the fabrication techniques now used to build integrated circuits could yet breathe vacuum electronics back to life.

At the NASA Ames Research Center, we've been working for the past few years to develop vacuum-channel transistors. Our research is still at an early stage, but the prototypes we've constructed show that this novel device holds extraordinary promise. Vacuum-channel transistors could work 10 times as fast as ordinary silicon transistors and may eventually be able to operate at terahertz frequencies, which have long been beyond the reach of any solid-state device. And they are considerably more tolerant of heat and radiation. To understand why, it helps to know a bit about the construction and functioning of good old-fashioned vacuum tubes.

Photo: Gregory Maxwell

Lightbulb Descendant: Vacuum tubes were an outgrowth of ordinary lightbulbs, a development spurred on by Thomas Edison’s investigations into the ability of heated filaments to emit electrons. This 1906 example, an early Audion tube, shows the close resemblance to a lightbulb, although the filament in this particular tube is not visible, having long ago burned out. That filament once acted as the cathode from which electrons flew toward the anode or plate, which is located in the center of the glass tube. Current flow from cathode to anode could be controlled by varying the voltage applied to the grid, the zigzag wire seen below the plate.

The thumb-size vacuum tubes that amplified signals in countless radio and television sets during the first half of the 20th century might seem nothing like the metal-oxide semiconductor field-effect transistors (MOSFETs) that regularly dazzle us with their capabilities in today’s digital electronics. But in many ways, they are quite similar. For one, they both are three-terminal devices. The voltage applied to one terminal – the grid for a simple triode vacuum tube and the gate for a MOSFET – controls the amount of current flowing between the other two: from cathode to anode in a vacuum tube and from source to drain in a MOSFET. This ability is what allows each of these devices to function as an amplifier or, if driven hard enough, as a switch.

How electric current flows in a vacuum tube is very different from how it flows in a transistor, though. Vacuum tubes rely on a process called thermionic emission: Heating the cathode causes it to shed electrons into the surrounding vacuum. The current in transistors, on the other hand, comes from the drift and diffusion of electrons (or of “holes,” spots where electrons are missing) between the source and the drain through the solid semiconducting material that separates them.

Why did vacuum tubes give way to solid-state electronics so many decades ago? The advantages of semiconductors include lower costs, much smaller size, superior lifetimes, efficiency, ruggedness, reliability, and consistency. Notwithstanding these advantages, when considered purely as a medium for transporting charge, vacuum wins over semiconductors. Electrons propagate freely through the nothingness of a vacuum, whereas they suffer from collisions with the atoms in a solid (a process called crystal-lattice scattering). What’s more, a vacuum isn’t prone to the kind of radiation damage that plagues semiconductors, and it produces less noise and distortion than solid-state materials.

The drawbacks of tubes weren’t so vexing when you just needed a handful of them to run your radio or television set. But they proved really troublesome with more complicated circuits. For example, the 1946 ENIAC computer, which used 17,468 vacuum tubes, consumed 150 kilowatts of power, weighed more than 27 metric tons, and took up almost 200 square meters of floor space. And it kept breaking down all the time, with a tube failing every day or two.

Chip in a Bottle: The simplest vacuum tube capable of amplification is the triode, so named because it contains three electrodes: a cathode, an anode, and a grid. Typically, the structure is cylindrically symmetrical, with the cathode surrounded by the grid and the grid surrounded by the anode. Operation is similar to that of a field-effect transistor, here with the voltage applied to the grid controlling the current flow between the other two electrodes. (Triode tubes often have five pins to accommodate two additional electrical connections for the heated filament.)

The transistor revolution put an end to such frustrations. But the ensuing sea change in electronics came about not so much because of the intrinsic advantages of semiconductors but because engineers gained the ability to mass-produce and combine transistors in integrated circuits by chemically engraving, or etching, a silicon wafer with the appropriate pattern. As the technology of integrated-circuit fabrication progressed, more and more transistors could be squeezed onto microchips, allowing the circuitry to become more elaborate from one generation to the next. The electronics also became faster without costing any more.

That speed benefit stemmed from the fact that as the transistors became smaller, electrons moving through them had to travel increasingly shorter distances between the source and the drain, allowing each transistor to be turned on and off more quickly. Vacuum tubes, on the other hand, were big and bulky and had to be fabricated individually by mechanical machining. While they were improved over the years, tubes never benefited from anything remotely resembling Moore’s Law.

But after four decades of shrinking transistor dimensions, the oxide layer that insulates the gate electrode of a typical MOSFET is now only a few nanometers thick, and just a few tens of nanometers separate its source and drain. Conventional transistors really can’t get much smaller. Still, the quest for faster and more energy-efficient chips continues. What will the next transistor technology be? Nanowires, carbon nanotubes, and graphene are all being developed intensively. Perhaps one of these approaches will revamp the electronics industry. Or maybe they’ll all fizzle.

We’ve been working to develop yet another candidate to replace the MOSFET, one that researchers have been dabbling with off and on for many years: the vacuum-channel transistor. It’s the result of a marriage between traditional vacuum-tube technology and modern semiconductor-fabrication techniques. This curious hybrid combines the best aspects of vacuum tubes and transistors and can be made as small and as cheap as any solid-state device. Indeed, making them small is what eliminates the well-known drawbacks of vacuum tubes.

Transistorizing the Vacuum Tube: A vacuum-channel transistor closely resembles an ordinary metal-oxide semiconductor field-effect transistor or MOSFET [left]. In a MOSFET, voltage applied to the gate sets up an electric field in the semiconductor material below. This field in turn draws charge carriers into the channel between the source and drain regions, allowing current to flow. No current flows into the gate, which is insulated from the substrate below it by a thin oxide layer. The vacuum-channel transistor the authors developed [right] similarly uses a thin layer of oxide to insulate the gate from the cathode and anode, which are sharply pointed to intensify the electric field at the tips.

In a vacuum tube, an electric filament, similar to the filament in an incandescent lightbulb, is used to heat the cathode sufficiently for it to emit electrons. This is why vacuum tubes need time to warm up and why they consume so much power. It’s also why they frequently burn out (often as a result of a minuscule leak in the tube’s glass envelope). But vacuum-channel transistors don’t need a filament or hot cathode. If the device is made small enough, the electric field across it is sufficient to draw electrons from the source by a process known as field emission. Eliminating the power-sapping heating element reduces the area each device takes up on a chip and makes this new kind of transistor energy efficient.

Another weak point of tubes is that they must maintain a high vacuum, typically a thousandth or so of atmospheric pressure, to avoid collisions between electrons and gas molecules. Under such low pressure, the electric field causes positive ions generated from the residual gas in a tube to accelerate and bombard the cathode, creating sharp, nanometer-scale protrusions, which degrade and, ultimately, destroy it.

These long-standing problems of vacuum electronics aren’t insurmountable. What if the distance between cathode and anode were less than the average distance an electron travels before hitting a gas molecule, a distance known as the mean free path? Then you wouldn’t have to worry about collisions between electrons and gas molecules. For example, the mean free path of electrons in air under normal atmospheric pressure is about 200 nanometers, which on the scale of today’s transistors is pretty large. Use helium instead of air and the mean free path goes up to about 1 micrometer. That means an electron traveling across, say, a 100-nm gap bathed in helium would have only about a 10 percent probability of colliding with the gas. Make the gap smaller still and the chance of collision diminishes further.

But even with a low probability of hitting, many electrons are still going to collide with gas molecules. If the impact knocks a bound electron from the gas molecule, it will become a positively charged ion, which means that the electric field will send it flying toward the cathode. Under the bombardment of all those positive ions, cathodes degrade. So you really want to avoid this as much as possible.

Fortunately, if you keep the voltage low, the electrons will never acquire enough energy to ionize helium. So if the dimensions of the vacuum transistor are substantially smaller than the mean free path of electrons (which is not hard to arrange), and the working voltage is low enough (not difficult either), the device can operate just fine at atmospheric pressure. That is, you don’t, in fact, need to maintain any sort of vacuum at all for what is nominally a miniaturized piece of “vacuum” electronics!

But how do you turn this new kind of transistor on and off? With a triode vacuum tube, you control the current flowing through it by varying the voltage applied to the grid – a meshlike electrode situated between the cathode and the anode. Positioning the grid close to the cathode enhances the grid’s electrostatic control, although that close positioning tends to increase the amount of current flowing into the grid. Ideally, no current would ever flow into the grid, because it wastes energy and can even cause the tube to malfunction. But in practice there’s always a little grid current.

To avoid such problems, we control current flow in our vacuum-channel transistor just as it’s done in ordinary MOSFETs, using a gate electrode that has an insulating dielectric material (silicon dioxide) separating it from the current channel. The dielectric insulator transfers the electric field where it’s needed while preventing the flow of current into the gate.

So you see, the vacuum-channel transistor isn’t at all complicated. Indeed, it operates much more simply than any of the transistor varieties that came before it.

Although we are still at an early stage with our research, we believe the recent improvements we’ve made to the vacuum-channel transistor could one day have a huge influence on the electronics industry, particularly for applications where speed is paramount. Our very first effort to fashion a prototype produced a device that could operate at 460 gigahertz – roughly 10 times as fast as the best silicon transistor can manage. This makes the vacuum-channel transistor very promising for operating in what is sometimes known as the terahertz gap, the portion of the electromagnetic spectrum above microwaves and below infrared.

Filling the Gap: Vacuum-channel transistors hold the promise of being able to operate at frequencies above microwaves and below infrared – a region of the spectrum sometimes known as the terahertz gap because of the difficulty that most semiconductor devices have operating at those frequencies. Promising applications for terahertz equipment include directional high-speed communications and hazardous-materials sensing.

Such frequencies, which run from about 0.1 to 10 terahertz, are useful for sensing hazardous materials and for secure high-speed telecommunications, to give just a couple of possible applications. But terahertz waves are difficult to take advantage of because conventional semiconductors aren’t capable of generating or detecting this radiation. Vacuum transistors could – pardon the expression – fill that void. These transistors might also find their way into future microprocessors, their method of manufacture being completely compatible with conventional CMOS fabrication. But several problems will need to be solved before that can happen.

Our prototype vacuum transistor operates at 10 volts, an order of magnitude higher than modern CMOS chips use. But researchers at the University of Pittsburgh have been able to build vacuum transistors that operate at just 1 or 2 V, albeit with significant compromises in design flexibility. We're confident we can reduce the voltage requirements of our device to similar levels by shrinking the distance between its anode and cathode. Also, the sharpness of these electrodes determines how much they concentrate the electric field, and the makeup of the cathode material governs how large a field is needed to extract electrons from it. So we might also be able to reduce the voltage needed by designing electrodes with sharper points or a more advantageous chemical composition that lowers the barrier for the electron escaping from the cathode. This will no doubt be something of a balancing act, because changes made to reduce operating voltage could compromise the long-term stability of the electrodes and the resultant lifetime of the transistor.

The next big step for us is to build a large number of vacuum-channel transistors into an integrated circuit. For that, we should be able to use many of the existing computer-aided design tools and simulation software developed for constructing CMOS ICs. Before we attempt this, however, we'll need to refine our computer models for this new transistor and to work out suitable design rules for wiring lots of them together. And we'll have to devise proper packaging methods for these 1-atmosphere, helium-filled devices. Most likely, the techniques currently used to package various microelectromechanical sensors, such as accelerometers and gyroscopes, can be applied to vacuum-channel transistors without too much fuss.

Admittedly, a great deal of work remains to be done before we can begin to envision commercial products emerging. But when they eventually do, this new generation of vacuum electronics will surely boast some surprising capabilities. Expect that. Otherwise you might end up feeling a bit like those military analysts who examined that Soviet MiG-25 in Japan back in 1976: Later they realized that its vacuum-based avionics could withstand the electromagnetic pulse from a nuclear blast better than anything the West had in its planes. Only then did they begin to appreciate the value of a little nothingness.

This article originally appeared in print as “The Device Made Of Nothin

Part 1 (up to ‘after four decades’)

Task 1

Find words which mean the following:
1. benefit;
2. to be behind;
3. having or seeming to have an ability to be everywhere;
4. finally, in the end;
5. to blind;
6. having a tendency to…;
7. in spite of the fact that;
8. to appear

Task 2

Say whether the following is true, false or is not mentioned:
1. Americans were greatly impressed by the Soviet fighters.
2. Since vacuum tubes were more power hungry and occupied a lot of room, they were replaced by transistors.
3. Vacuum electronics could still prove useful nowadays.
4. Vacuum tubes are more heat and radiation resistant than transistors.
5. The only drawback of vacuum -channel transistors is that they emit a lot of heat.
6. They are much better than ordinary transistors and can operate at frequencies impossible for ordinary transistors.

Task 3

Answer the following questions.
1. Why were military analysts surprised when they examined the Soviet plane?
2. What are the advantages of vacuum-channel transistors?
3. How is current controlled in vacuum tubes and transistors?
4. Why did transistors replace vacuum tubes?
5. What makes electronics faster?
6. Can we say that the basic principles of work of vacuum tubes and transistors are the same? Why? Why not?

Part 2 (from ‘after four decades’ up to the end)

Task 1

Find words which mean the following:

1. analogously;
2. complex or rich in detail;
3. to result from;
4. to look like;
5. in proper order or sequence;
6. average

Task 2

Say whether the following is true, false or is not mentioned:

1. Vacuum tubes and MOSFET transistors have much in common.
2. If it were not for efficiency, price and life-time, vacuum tubes would prove better than transistors.
3. Vacuum-channel transistors are much more expensive than conventional ones.
4. They use the best of two worlds.
5. Since vacuum-channel transistors have no filament, they are more economical than vacuum tubes.
6. The problems of vacuum electronics are impossible to solve.
7. The vacuum in very small vacuum-channel transistors needn’t be as high as in vacuum tubes.
8. Vacuum -channel transistors could have a great effect on electronics due to their higher speed.
9. A great limitation of vacuum-channel transistors is a higher operating voltage and nothing can be done about it.
10. The operating voltage in a vacuum-channel transistor is proportional to the distance between the anode and the cathode.

Task 3

Answer the following questions:

1. What device uses the best of two worlds?
2. What makes it economical?
3. How can the problems of vacuum electronics be solved?
4. Why are the high speeds of vacuum transistors so important?
5. Will new technologies be required to produce vacuum transistors? Why? Why not?
6. Where did the military analysts go wrong?

12. A TRANSISTOR THAT STANDS UP TO BLISTERING NUCLEAR REACTOR TEMPERATURES

By Prachi Patel

Dan Hixson/University of Utah

University of Utah electrical engineers test a microplasma transistor by applying a voltage through four electrodes touching the surface of the transistor.

Wonderful as silicon-based transistors are, they break down at temperatures above 350 °C. For higher-temperature environments, such as those found in jet engines and deep oil wells, researchers have had to turn to other options such as silicon carbide circuits, which can survive up to 550 °C.

Now, researchers at the University of Utah have made tiny plasma-based transistors that work at the blistering temperatures found inside nuclear reactors. While plasma transistors were first reported five years ago, the new devices are 500 times smaller than those early versions.

The new micro-plasma transistors work at temperatures of up to 790 °C. They could be used to make electronics for controlling robots that conduct tasks inside a nuclear reactor, says Massood Tabib-Azar, the professor of electrical and computer engineering at the University of Utah who developed the devices. Such extreme-temperature logic circuits could also control nuclear reactors in case of emergencies or nuclear attacks. Tabib-Azar and his postdoctoral researcher, Pradeep Pai, reported the plasma transistors online today in the journal

In a conventional three-terminal field-effect transistor, the voltage applied at the gate terminal controls the current flowing through a semiconductor channel. A voltage that is above a certain threshold turns the device on.

The channel in a plasma transistor consists of a partially ionized gas, or plasma, instead of a semiconductor. An electron emitter, typically silicon, injects electrons into the plasma when a voltage is applied to it. Plasmas are generated at very high temperatures, making them suitable for an extreme-environment transistor. Today’s plasma transistors, which are used in light sources and medical instruments, are about 500 micrometers long and operate at more than 300 volts, requiring special high-voltage sources.

The new devices are between 1 and 6 microns in length and operate at one-sixth the voltage. Tabib-Azar and Pai made the transistors by first depositing layers of a metal alloy to form the gate on a 10-centimeter glass wafer. They deposited a thin layer of silicon on top of the gate. Then they etched away portions of the silicon film using a chemically reactive gas, creating cavities and empty spaces that they could fill with the plasma to form the transistor's channel. They used helium as the plasma source.

The researchers are working on connecting the devices to make logic circuits that they plan to test in the experimental nuclear reactor at the University of Utah.

In addition to working in nuclear reactors, the new extreme-temperature transistors could be used to generate X-rays. Instead of using bulky lenses and X-ray shaping devices, engineers could use these tiny devices to pattern microscale devices in silicon. Or this type of transistor could be incorporated in a smartphone, creating an X-ray imaging source to collect images of wounded soldiers in the battlefield, says Tabib-Azar.

Task 1

Find words which mean the following:
1. very hot;
2. to direct one’s interest or attention;
3. ordinary;
4. very small;
5. a level at which something starts to happen or have an effect;
6. an unexpected situation;
7. a metal material consisting of two or more metals.

Task 2

Say whether the following is true, false or is not mentioned:
1. Silicon based transistors stop working at high temperatures.
2. Silicon-carbide transistors are the only way out.
3. Plasma transistors haven’t changed much since the day they were invented.
4. They will still operate in a nuclear explosion epicentre.
5. A voltage below a certain threshold will turn a plasma transistor off.
6. The new transistors still need a very high voltage.
7. Scientists intend to join several devices making a logic circuit which will be operable in nuclear reactors.
8. The new plasma transistors could produce x-rays which by means of lenses could pattern microscale devices in silicon.

Task 3

Answer the following questions:
1. What is a great disadvantage of a silicon transistor?
2. How does an ordinary 3terminal FET transistor work?
3. What about the new high temperature transistor?
4. How is the new device produced?
5. Where does plasma come from?
6. Is plasma transistors use limited by nuclear reactors, only? Why? Why not?

13. BREAKING NETWORK LOGJAMS

An approach called network coding could dramatically enhance the efficiency and reliability of communications networks. At its core is the strange notion that transmitting evidence about messages can be more useful than conveying the messages themselves By RALF KOETTER, MURIEL MÉDARD and MICHELLE EFFROS.

The history of modern communications systems has been marked by flashes of startling insight.

Claude E. Shannon, mathematician and engineer, launched one such revolution almost 60 years ago by laying the foundation of a new mathematical theory of communications--now known as information theory. Practical outgrowths of his work, which dealt with the compression and reliable transmission of data, can be seen today in the Internet, in landline and wireless telephone systems, and in storage devices, from hard drives to CDs, DVDs and flash memory sticks.

Shannon tackled communications over phone lines dedicated to individual calls. These days, information increasingly travels over shared networks (such as the Internet), in which multiple users simultaneously communicate through the same medium--be it a cable, an optical fiber or, in a wireless system, air. Shared networks can potentially improve the usefulness and efficiency of communications systems, but they also create competition for communal resources. Many people must vie for access to, say, a server offering downloadable songs or to a wireless hot spot.

The challenge, then, is to find ways to make the sharing go smoothly; parents of toddlers will recognize the problem. Network operators frequently try to solve the challenge by increasing resources, but that strategy is often insufficient. Copper wires, cables or fiber optics, for instance, can now provide high bandwidth for commercial and residential users yet are expensive to lay and difficult to modify and expand. Ultrawideband and multiple-antenna transmission systems can expand the number of customers served by wireless networks but may still fail to meet ever increasing demand.

Techniques for improving efficiency are therefore needed as well. On the Internet and other shared networks, information currently gets relayed by routers--switches that operate at nodes where signaling pathways, or links, intersect. The routers shunt incoming messages to links heading toward the messages' final destinations. But if one wants efficiency, are routers the best devices for these intersections? Is switching even the right operation to perform?

Until seven years ago, few thought to ask such questions. But then Rudolf Ahlswede of the University of Bielefeld in Germany, along with Ning Cai, Shuo-Yen

Robert Li and Raymond W. Yeung, all then at the University of Hong Kong, published groundbreaking work that introduced a new approach to distributing information across shared networks. In this approach, called network coding, routers are replaced by coders, which transmit evidence about messages instead of sending the messages themselves. When receivers collect the evidence, they deduce the original information from the assembled clues.

Although this method may sound counterintuitive, network coding, which is still under study, has the potential to dramatically speed up and improve the reliability of all manner of communications systems and may well spark the next revolution in the field. Investigators are, of course, also exploring additional avenues for improving efficiency; as far as we know, though, those other approaches generally extend existing methods.

Bits Are Not Cars

Ahlswede and his colleagues built their proposal in part on the idea, introduced by Shannon, that transmitting evidence about data can actually be more useful than conveying the data directly. They also realized that a receiver would be able to deduce the original data once enough clues had been gathered but that the receiver would not need to obtain all of the evidence emitted. One kind of clue could be replaced by another, and all that was important was receiving some combination of clues that, together, would reveal the original message. (Receivers would be able to make sense of the evidence if they were informed in advance about the rules applied to generate it or if instructions on how to use the evidence were included in the evidence itself).

Network coding breaks with the classic view that communications channels are analogous to roads and that bits are like the cars that travel those roads. But an understanding of the transportation model of communications is useful for grasping how the new scheme works and why it has such promise.

Shannon proved mathematically that every channel has a capacity--an amount of information it can relay during any given time frame--and that communications can proceed reliably as long as the channel's capacity is not exceeded. In the transportation analogy, a road's capacity is the number of cars per second it can handle safely. If traffic stays below capacity, a car entering the road at one end can generally be guaranteed to exit at the other end unchanged (barring the rare accident). Engineers have built increasingly complex communications systems based on the transportation model. For example, the phone systems Shannon pondered dedicate a distinct "road" to every conversation; two calls over traditional phone lines never share a single line at the same time and frequency.

Computer networks – and the Internet in particular – are essentially a maze of merging, branching and intersecting roads. Information traveling from one computer to another typically traverses several roads en route to its destination. Bits from a single message are grouped into packets (the carpools or buses of the information superhighway), each of which is labeled with its intended destination. Routers sit at the intersections of the roads, examine each packet's header and forward that packet toward its destination.

Ironically, the very transportation model that fueled today's sophisticated communications systems now stands in the way of progress. After all, bits are not cars. When two vehicles converge on the same narrow bridge, they must take turns traversing the bottleneck. When two bits arrive at a bottleneck, however, more options are possible--which is where network coding comes in.

How It Works

The hypothetical six-node digital network depicted in the box on these two pages can help clarify those options. Recall that in computers, all messages take the form of a string of binary code. Imagine that each link, or road, in this network can carry one bit--be it a 0 or a 1--per second and only in the direction designated by the corresponding arrow. Amy, a network user at node A, hopes to send information at one bit per second to Dana at node D. Meanwhile Ben at node B hopes to send, at exactly the same time and rate, information to Carl at node C. Can both Amy's and Ben's demands be satisfied simultaneously without exceeding any of the links' capacities?

In a router system [see leftmost illustration], the outlook seems bleak. Both paths, from Amy to Dana and from Ben to Carl, require traversing link 5. This link becomes the equivalent of a narrow, one-lane bridge. The router at node E, where link 5 starts, receives a total of two bits per second (one from link 2 and one from link 3), but because link 5's capacity is one, the router can send only one bit per second along it. In the transportation model, such bottlenecks cause nightmare traffic jams, with more and more bits piling up over time, waiting their turn.

In the new approach [see illustrations above], though, the plain router would be replaced by a coder, which would have more options than would be open to a traffic cop. Instead of relaying the actual bit streams collected at the bottleneck, the coder could send quite different information. It could, for example, add up the number of 1s that arrive during any given second and transmit a 0 if that sum is even. If the sum is odd, the device could transmit a 1. So, if link 5 `simultaneously receives a 1 and a 0 from links 2 and 3, it carries a 1. If either two 0s or two 1s are received from links 2 and 3, link 5 carries a 0. The result then gets sent by router F down links 6 and 7 to Carl and Dana, respectively.

This approach replaces each pair of bits at node E with a hybrid of the two. Such a bit stream seems ridiculous. Our proposed coder has done the equivalent of combining one phone conversation with another in a way that obscures both. The apparent absurdity of the approach is precisely why it went uninvestigated for so long.

But sometimes apparent madness is true innovation. A hybrid bit stream may describe neither transmission perfectly, yet it can supply evidence about both. Suppose we additionally send Amy's missive to Carl along link 1 and Ben's to Dana along link 4. Sending these two messages uses network resources (links 1 and 4) that the routing system could not usefully employ for meeting Amy's and Ben's demands. Carl's node receives Amy's transmission and knows for each instant (from link 6) whether the number of 1s in the pair of messages issued by Amy and Ben is even or odd. If Carl's node is programmed to also "know" the rule used by the coders at the start of link 5 or if it can infer the rule from the evidence itself, the collected evidence will enable it to decipher the message sent by Ben. And Dana's node will similarly uncover Amy's message.

Clear Benefits

This strategy accomplishes two goals that were unthinkable given the limitations of the transportation model. First, it enables the bit leaving a node to travel two paths simultaneously, something a car cannot do. Second, it allows a pair of bit streams arriving at the head of a bottleneck to combine into a single stream, whereas two cars converging on one narrow bridge cannot become a single entity; one would have to wait for the other to pass before it could proceed across the bridge.

The data-handling approach exemplified by our six-node model (a minor variation on one first given by Ahlswede and his colleagues in 2000) can potentially increase the capacity of a network without requiring the addition of extra conduits because it avoids logjams. Using routing alone, our six-node network could sustain simultaneous transmissions averaging one half of a bit per second. (Because the two competing transmissions would have to share link 5, the effective data rate would be one bit per two seconds, or one half of a bit per second, for each of the competing demands.) With network coding, the same system supports simultaneous transmissions at one bit per second. So, here, network coding doubles capacity.

Sometimes network coding could yield even bigger capacity gains, sometimes none. But the approach would never decrease the capacity of a network because, at worst, it would precisely mimic the actions of router systems. It should also increase reliability and resistance to attacks in relatively substantial networks, because the interchangeable nature of evidence means that some packets of evidence can be lost without creating problems.

Lessons from Multicast Networks

So far much of the research into implementing network coding has focused on multicast networks--in which all receivers need to get the same information. Internet video games rely on multicast systems to update every player each time one makes a move. Webcasts of videos or live sporting events and new software released electronically to a large group of customers also travel over multicast networks. Today such networks still use routers, and a return to the transportation analogy helps to explain why designing them is usually quite difficult.

Imagine the country's highways teeming with cars. Each router is like a police officer directing traffic at a single intersection. Incoming cars join the queue behind vehicles that arrived before them. The officer reads each car's destination in turn and directs it on its way. The goal in system design is for each router to direct traffic in a way that not only speeds each subsequent car to its intended destination but also allows the nation's transportation system as a whole to satisfy as many drivers as possible.

Even a central designer with a complete map of all the nation's roads in hand would be hard put to determine the best possible strategy for every router to follow. The difficulty increases as the network changes over time: rush hours, road repairs, accidents and sporting events mean the roadways and the demands placed on them change constantly.

Intuition might suggest that designing a system reliant on network coding should be even harder, because there are more options to consider. A node could forward data unchanged, thereby mimicking a router. But it might also mix two or more incoming data streams before sending them on, and how it mixes them might also be open to consideration; further, different nodes might use different algorithms.

Luckily, this logic is flawed. Sometimes adding more options actually simplifies things. Without coding, architects of a multicast system would need to enumerate as many paths as possible from the transmitter to each receiver and then determine how many of those paths the network could support simultaneously. Even for simple networks, finding and testing all combinations of paths would be a dizzying task.

In contrast, a multicast system using network coding would be rather easy to design. The startling truth is that addition and multiplication are the only mathematical functions that coded networks need apply. Also, even if the function, or rule, programmed into each coder in a network is chosen independently of the message and the other coding functions and without any knowledge of the network layout, the system as a whole will, with extremely high probability, operate at peak performance. Even if the system changes over time, as can happen in mobile or reconfigurable networks, the network will continue to perform optimally without requiring redesign. To learn why, see the illustration.

Tomorrow's Networks

The operation of networks, then, will be very different if coders replace routers. The way our messages traverse networks will change: they will not only share "the road" with other transmissions but may become intimately entangled with traffic from a variety of other sources. Some might fear that such entanglement would compromise the security of the messages. More likely, though, traffic traversing networks would become a locally undecipherable algebraic stream. Users on the network would unwittingly collaborate to one another's mutual advantage, allowing not just higher rates or faster downloads of data but also, in the case of wireless networks, an improvement in energy efficiency. (Because each wireless transmission consumes energy, a node can reduce consumption by mixing together the information intended for several neighbors and sending only a single transmission.)

By changing how networks function, network coding may influence society in ways we cannot yet imagine.

Moreover, delays in downloading videos and lost cell phone calls will be far less common. On the Internet, routers fail or are taken down for maintenance and data packets are dropped all the time. That is why people must sometimes rerequest Web pages and why a site sometimes comes up slowly. Reliability will increase with network coding, because it does not require every single piece of evidence to get through.

And network managers will provide such benefits without having to add new communications channels, because better use will be made of existing channels. Network coding will thereby complement other communications technologies, allowing users to get as much as possible out of them.

Sometimes users will know that network coding is operating, because it may modify how some common applications, such as peer-to-peer downloads, function. Today someone seeking to download a file searches for a collaborating user on whose machine the file resides. In a system using network coding, the file would no longer be stored as a whole or in recognizable pieces.

But users would not personally have to figure out how to find the evidence needed to obtain the desired files. A request sent into a network from a user's computer or phone would cause either that individual's computer or a local server to scavenge through the network for pieces of evidence related to a file of interest. The gathered evidence, consisting of algebraically mixed pieces of information relating to the desired file, would help recover that file. Instead of putting together a puzzle whose pieces are recognizable fragments of a whole, the server or an individual's computer would solve a collection of algebraic equations. And, all the while, most people would remain blissfully unaware of these operations--just as most of us are ignorant of the complicated error-correction operations in our cell phones.

The military has recognized the robustness of network coding and is now funding research into its use in mobile ad hoc networks, which can form on the fly. Such networks are valuable in highly changeable environments, such as on the battlefield, where reliable communications are essential and establishing and maintaining an infrastructure of fiber-optic cables or cell towers is difficult. In an ad hoc network, every soldier's radio becomes a node in a communications system, and each node seeks out and establishes connections to neighboring nodes; together these connections establish a network's links. Every node can both send and receive messages and serve as an intermediary to pass along messages intended for other receivers. This technique extends communications capabilities far beyond the transmission range of a single node. It also allows enormous flexibility, because the network travels with the users, constantly reconfiguring and reestablishing connections as needed.

By changing how networks function, network coding may influence society in ways we cannot yet imagine. In the meantime, though, those of us who are studying it are considering the obstacles to implementation. Transitioning from our router-based system to a network-coded one will actually be one of the more minor hurdles. That conversion can be handled by a gradual change rather than a sudden overhaul; some routers could just be reprogrammed, and others not built to perform coding operations would be replaced little by little.

A bigger challenge will be coping with issues beyond replacing routers with coders. For instance, mixing information is a good strategy when the receiving node will gather enough evidence to recover what it desires from the mixture. This condition is always met in multicast networks but may not be the case in general. Moreover, in some circumstances, such as when multiple multicasts are transmitted, mixing information can make it difficult or impossible for users to extract the proper output. How, then, can nodes decide which information can and cannot be mixed when multiple connections share the same network? In what ways must network coding in wireless networks differ from its use in wired ones? What are the security advantages and implications of network coding? How will people be charged for communications services when one person's data are necessarily mixed with those of other users? In collaborations that span the globe, we and others are pondering how to unravel such knots even as we strive to enhance the capabilities of the communications networks that have become such an integral part of so many lives.

Part 1 (up to <clear benefits>)

Task 1

Find words or expressions meaning the following:
1. to improve;
2. to deal with (a problem or difficulty);

3. to compete;

4. to understand or explain;

5. gloomy, unlikely to improve;

6. absurd;

7. to conceal, to make it difficult to understand;

8. to reason by deduction.

Task 2

Find the paragraph/paragraphs which
1. doubt(s) if switches are the most efficient devices;
2. deal(s) with the main drawback of shared networks;
3. explain(s) the main idea behind the new approach;
4. mention(s) obstacles in the way of development;
5. say(s) that what seems crazy proves to be a discovery;
6. explain(s) the difference between transport networks and computer networks;
7. explain(s) how messages are transmitted in the imaginary network mentioned in the text;
8. explain(s) why nobody has paid any attention to the new approach before.

Task 3

Answer the following questions:
1. What is the main problem of shared networks?
2. What are the ways of solving it?
3. Why is it not enough to increase resources to cope with the problem?
4. How does the new approach work?
5. What new idea is it based on?

Part 2 (from ‘clear benefits’ up to the end)

Task 1

Find words or expressions meaning the following:
1. to lead to;
2. crowded with, full of;
3. without knowledge or intention;

4. because of;

5. the property of being strong and not likely to break;

6. obstacle;

7. to think over, consider;

8. to try very hard to achieve something`;

9. to disentangle, unknot.

Task 2

Find the paragraph/paragraphs which say(s) that
1. the new approach does not always improve the situation;
2. the idea that having more options makes things worse is wrong;
3. people will not know or care where to find the information about the file they need;
4. explain(s)why network coding can increase capacity;
5. explain(s) why some pages and sites are not accessed fast enough;
6. the new approach raises new questions which have not been answered yet;
7. which explain(s) possible new applications of the new approach due to its durability
8. mentions the difficulties on the way of implementing the new approach

Task 3

Say whether the following is true, false, or is not mentioned:
1. In network coding the number of bits per second in one six-node model can be unlimited.
2. Routers are similar to traffic cops as both of them have to let through as much traffic as possible and as fast as possible.
3. Mixing all the traffic will make messages more insecure.
4. Since a lot of changes will have to be made, traffic will be not only faster but also much more expensive.
5. With network coding the time out error will disappear.
6. In network coding systems stored files will be in a mess.
7. Network coding will replace all the existing techniques.
8. The hardest thing will be to switch over from a router-based system to a network-coded one.
9. The change will take some time and will proceed step by step.

14. NANOWIRE TRANSISTORS COULD KEEP MOORE’S LAW ALIVE

Researchers are perfecting ways to produce gate-all-around devices

By Alexander Hellemans

Illustration: Emily Cooper Gate-All-Around Transistors: In a new design, the transistor channel is made up of an array of vertical nanowires. The gate surrounds all the nanowires, which improves its ability to control the flow of current. Platinum-based source and drain contacts sit at the top and bottom of the nanowires.

The end of Moore’s Law has been predicted again and again. And again and again, new technologies, most recently FinFETs, have dispelled these fears. Engineers may already have come up with the technology that will fend off the next set of naysayers: nanowire FETs (field-effect transistors).

In these nanodevices, current flows through the nanowire or is pinched off under the control of the voltage on the gate electrode, which surrounds the nanowire. Hence, nanowire FETs’ other name: “gate-all-around” transistors. However, because of their small size, single nanowires can’t carry enough current to make an efficient transistor.

The solution, recent research shows, is to make a transistor that consists of a small forest of nanowires that are under the control of the same gate and so act as a single transistor. For example, researchers at Hokkaido University and from the Japan Science and Technology Agency reported last year in Nature a gate-all-around nanowire transistor consisting of 10 vertical indium gallium arsenide nanowires grown on a silicon substrate. Although the device’s electrical properties were good, the gate length – a critical dimension – was 200 nanometers, much too large for the tiny transistors needed to power the microprocessors of the 2020s.

Now two researchers working in France, Guilhem Larrieu of the Laboratory for Analysis and Architecture of Systems, in Toulouse, and Xiang Lei Han of the Institute for Electronics, Microelectronics, and Nanotechnology, in Lille, report the creation of a nanowire transistor that could be scaled down to do the job. It consists of an array of 225 doped-silicon nanowires, each 30 nm wide and 200 nm tall, vertically linking the two platinum contact planes that form the source and drain of the transistor. Besides their narrowness, what’s new is the gate: A single 14-nm-thick chromium layer surrounds each nanowire midway up its length.

That thickness, the gate length, is the key. “The advantage of an all-around gate allows the creation of shorter gates, without loss of control on the current through the channel,” explains Larrieu. “We demonstrated the first vertical nanowire transistor with such a short gate.” An all-around gate will be a must if gate lengths are to get smaller than 10 nm, he says. In that scheme, “the size of the gate depends only on the thickness of the deposited layer; there is no complicated lithography involved," he adds.

The nanowires were of an unusual construction. Unlike with most vertical nanowire transistor prototypes, in which the nano wires are grown upward from a substrate, the French duo created their nanowires by starting out with a block of doped silicon and then etching away material to leave nano pillars. In between the pillars, they deposited an insulating layer to about half the pillars' height. Then they deposited the 14 nm of chromium and filled the remaining space with another insulating layer. "We tried to make the process completely compatible with current technology used in electronics. No new machines will have to be invented," says Larrieu. The researchers have plans to try to go below 10-nm gate length, and also to use indium gallium arsenide nanowires because of the better electron mobility.

Kelin Kuhn, director of advanced device technology at Intel's Hillsboro, Ore., location, agrees that all-around gate structures have some key advantages. Of all the CMOS-style advanced devices, they're generally expected to provide the best gate control for very short channels, she says.

Davide Sacchetto, a researcher at the École Polytechnique Fédérale de Lausanne, agrees: "The fabrication of the gate is interesting, and you get a small gate length." However, the advantage is lost if the nanowires are too long – 200 nm in this case – and the channel is only a small part of the total length of the nanowire, he says. "Even a difference of 5 nm would make a huge difference in the drain current."

According to Judy Hoyt, a researcher at the Microsystems Technology Laboratories at MIT, gate-all-around technology is now under study at a number of university labs worldwide. But as the nanowire transistors are more complex than the FinFETs, will this effort allow Moore's Law to live longer and fit even more transistors on a chip? "The jury is still out," says Hoyt. It depends on what the fabrication process and the structure will be, she says. "You really have to get the physics right, and that is what all these efforts are based on".

Task 1

Find words meaning the following:
1. To suggest an idea;
2. To make something go away;
3. To reduce;
4. In addition to;
5. Included, connected with;
6. Able to exist or be used without causing problems.

Task 2

Say whether the following is true, false or not mentioned:

1. One nanochip is enough to make a good transistor.
2. The new idea is to make a lot of nanowire work as a single transistor.
3. The new device's gate length should not be greater than 200 nm.
4. You can't scale down a nanowire transistor endlessly.
5. An all – around gate allows gates to be shorter.
6. The size of the gate is directly proportional to the thickness of the deposited layer.
7. These new devices mean a complete change of technology and equipment.
8. Whether they mean the end of Moore's law is still unclear.

Task 3

Answer the following questions:

1. Why cannot single nanowires make a good transistor?
2. What is the way out?
3. What was a great drawback of the new device?
4. What is the most important factor of an all-around transistor?
5. What is the difference between ordinary nanowires and the ones mentioned above?

15. MAGNETIC LOGIC MAKES FOR MUTABLE COMPUTER CHIPS

A new alternative transistor relies on a semiconductor that can be switched with magnetism instead of electricity. The approach could help make circuitry more malleable and lead to more efficient and reliable gadgets

By Geoff Brumfiel and Nature magazine

MAGNETIC LOCK: In a circuit made of the semiconductor indium antimonide, a magnetic field can lift electrons over positively charged holes, switching the device on – or deflect them into the holes, turning it off. Image: Nature magazine

Software can transform a computer from a word processor to a number cruncher to a video telephone. But the underlying hardware is unchanged. Now, a type of transistor that can be switched with magnetism instead of electricity could make circuitry malleable too, leading to more efficient and reliable gadgets, from smart phones to satellites.

Transistors, the simple switches at the heart of all modern electronics, generally use a tiny voltage to toggle between ‘on’ and ‘off’. The voltage approach is highly reliable and easy to miniaturize, but has its disadvantages. First, keeping the voltage on requires power, which drives up the energy consumption of the microchip. Second, transistors must be hard-wired into the chips and can’t be reconfigured, which means computers need dedicated circuitry for all their functions.

A research group based at the Korea Institute of Science and Technology (KIST) in Seoul, South Korea, has developed a circuit that may get around these problems. The device, described in a paper published on Nature’s website on 30 January, uses magnetism to control the flow of electrons across a minuscule bridge of the semiconducting material indium antimonide (S. Joo et al. Nature http://dx.doi.org/10.1038/nature11817; 2013). It is “a new and interesting twist on how to implement a logic gate”, says Gian Salis, a physicist at IBM’s Zurich Research Laboratory in Switzerland.

The bridge has two layers: a lower deck with an excess of positively charged holes and an upper deck filled predominantly with negatively charged electrons. Thanks to the unusual electronic properties of the indium antimonide, the researchers can control the flow of electrons across the bridge using a perpendicular magnetic field. When they set the field in one direction, electrons are steered away from the positive bottom deck and flow freely. When the magnetic field is flipped, the electrons crash into the lower deck and recombine with the holes – effectively turning the switch off (see ‘Magnetic lock’).

The ability of a magnetic logic gate to hold the switch on or off without a voltage “could lead to great reduction of energy consumption”, says study co-author Jin Dong Song, a physicist at KIST. Even more impressively, the magnetic switches “can be handled like software”, he says, by simply flipping the field to enable or disable a circuit. Thus a mobile phone could, for example, reprogram a bit of its microcircuitry to process video while its user watched a clip on YouTube, then switch the chip back to signal processing to take a phone call. This could greatly reduce the volume of circuitry needed inside the phone.

Such reconfigurable logic could be invaluable in satellites, adds Mark Johnson of the Naval Research Laboratory in Washington DC, a co-author of the paper. If part of a chip failed in orbit, another sector could simply be reprogramed to take over. “You’ve healed the circuit and you’ve done it from Earth,” he says.

To really catch on, however, the magnetic logic would have to be integrated with existing silicon-based technologies. That may not be easy. For one thing, indium antimonide, the semiconductor crucial to the circuits, doesn’t lend itself well to manufacturing processes used to make modern electronics, according to Junichi Murota, a researcher working with nanoelectronics at Tohoku University in Japan. But Johnson says that it may eventually be possible to build similar bridges with silicon.

Integrating the miniature magnets needed to control the devices into a normal chip wouldn’t be easy either. Companies should be able to solve these challenges, but only if they decide the devices are worthwhile, says Salis. At the moment, he adds, it is not clear whether the devices will perform well at the sizes needed for a practical chip – much smaller than the micrometer dimensions of the prototypes.

But Johnson notes that magnetism is already catching on in circuit design: some advanced devices are beginning to use a magnetic version of random access memory, a type of memory that has historically been built only with conventional transistors. “I think a shift is already under way,” he says.

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Task 1

Find words or expressions meaning the following:

1. Flexible;
2. To increase;
3. very small;
4. to avoid, evade;
5. an unexpected feature or change in a situation;

6. finally;
7. to become wide-spread, popular.

Task 2

Say whether the following is true, false or is not mentioned:

1. A computer may have lots of functions depending on its programs but it still remains a computer in terms of its components.
2. Since transistors are getting smaller and smaller, the voltage applied to them gets smaller, too, reducing the power consumption of the microchip.
3. The new approach suggests using a magnetic field to create a logic gate.
4. You still have to apply a voltage to a magnetic logic switch to keep the magnetic field on.
5. Using magnetic switches may result in reducing the number of components in electronic gadgets.
6. There are no obstacles in the way of using magnetic logic.
7. MRAM devices can have a wide range of applications from smartphones to tracking a rocket.

Task 3

Answer the following questions:

1. Why do you think a computer remains a computer whatever functions it has?
2. What is wrong with traditional approach to modern electronics?
3. How does the new gate work?
4. What changes result from a magnetic logic gate?
5. How can it be used?
6. Why hasn’t it gained popularity?
7. Why is it difficult to integrate tiny magnets into a normal chip?

16. TOWARD FASTER TRANSISTORS: PHYSICISTS DISCOVER PHYSICAL PHENOMENON THAT COULD BOOST COMPUTERS' CLOCK SPEED

ScienceDaily In the 1980s and '90s, competition in the computer industry was all about «clock speed» – how many megahertz, and ultimately gigahertz, a chip could boast. But clock speeds stalled out almost 10 years ago: Chips that run faster also run hotter, and with existing technology, there seems to be no way to increase clock speed without causing chips to overheat.

In this week's issue of the journal Science, MIT researchers and their colleagues at the University of Augsburg in Germany report the discovery of a new physical phenomenon that could yield transistors with greatly enhanced capacitance – a measure of the voltage required to move a charge. And that, in turn, could lead to the revival of clock speed as the measure of a computer's power.

In today's computer chips, transistors are made from semiconductors, such as silicon. Each transistor includes an electrode called the gate; applying a voltage to the gate causes electrons to accumulate underneath it. The electrons constitute a channel through which an electrical current can pass, turning the semiconductor into a conductor.

Capacitance measures how much charge accumulates below the gate for a given voltage. The power that a chip consumes, and the heat it gives off, are roughly proportional to the square of the gate's operating voltage. So lowering the voltage could drastically reduce the heat, creating new room to crank up the clock.

MIT Professor of Physics Raymond Ashoori and Lu Li, a postdoc and Pappalardo Fellow in his lab – together with Christoph Richter, Stefan Paetel, Thilo Kopp and Jochen Mannhart of the University of Augsburg – investigated the unusual physical system that results when lanthanum aluminate is grown on top of strontium titanate. Lanthanum aluminate consists of alternating layers of lanthanum oxide and aluminum oxide. The lanthanum-based layers have a slight positive charge; the aluminum-based layers, a slight negative charge. The result is a series of electric fields that all add up in the same direction, creating an electric potential between the top and bottom of the material.

Ordinarily, both lanthanum aluminate and strontium titanate are excellent insulators, meaning that they don't conduct electrical current. But physicists had speculated that if the lanthanum aluminate gets thick enough, its electrical potential would increase to the point that some electrons would have to move from the top of the material to the bottom, to prevent what's called a «polarization catastrophe.» The result is a conductive channel at the juncture with the strontium titanate – much like the one that forms when a transistor is switched on. So Ashoori and his collaborators decided to measure the capacitance between that channel and a gate electrode on top of the lanthanum aluminate.

They were amazed by what they found: Although their results were somewhat limited by their experimental apparatus, it may be that an infinitesimal change in voltage will cause a large amount of charge to enter the channel between the two materials. «The channel may suck in charge – shoomp! Like a vacuum,» Ashoori says. «And it operates at room temperature, which is the thing that really stunned us.»

Indeed, the material's capacitance is so high that the researchers don't believe it can be explained by existing physics. «We've seen the same kind of thing in semiconductors,» Ashoori says, «but that was a very pure sample, and the effect was very small. This is a super-dirty sample and a super-big effect.» It's still not clear, Ashoori says, just why the effect is so big: «It could be a new quantum-mechanical effect or some unknown physics of the material.»

There is one drawback to the system that the researchers investigated: While a lot of charge will move into the channel between materials with a slight change in voltage, it moves slowly – much too slowly for the type of high-frequency switching that takes place in computer chips. That could be because the samples of the material are, as Ashoori says, «super dirty»; purer samples might exhibit less electrical resistance. But it's also possible that, if researchers can understand the physical phenomena underlying the material's remarkable capacitance, they may be able to reproduce them in more practical materials.

Triscone cautions that wholesale changes to the way computer chips are manufactured will inevitably face resistance. «So much money has been injected into the semiconductor industry for decades that to do something new, you need a really disruptive technology» he says.

«It's not going to revolutionize electronics tomorrow» Ashoori agrees. «But this mechanism exists, and once we know it exists, if we can understand what it is, we can try to engineer it».

Task 1

Find words or expressions meaning the following:
1. to result in;
2. increased;
3. radically;
4. to make something more intense;
5. to form a theory or conclusion about something without strong evidence;
6. to be surprised greatly;
7. to astonish or shock somebody so that they are temporarily unable to react;
8. to show.

Task 2

Say whether the following is true, false or not mentioned:

1. The author implies that clock speed is not used to indicate computer power nowadays.
2. Too many electrons under the gate results in the gate turning into a conductor and letting the current flow freely.
3. The power of the chip and the heat it produces are directly proportional to the gate's operating voltage.
4. The above relationship is an exact one.
5. What surprised the scientists was that a very small voltage change results in a great increase in the amount of charge between strontium titanate and lanthanium aluminate.
6. Impurities in the material dramatically increased the effect.
7. The new idea will be opposed by most manufacturers as it will lead to great changes in the manufacturing process will be very hard to realise.

Task 3

Answer the following questions:

1. How is a semiconductor turned into a conductor?
2. What is the relation between the chip's power and the heat it radiates?
3. What new phenomenon was used by physisists?
4. Why were they so surprised?
5. Has the system any negative points?
6. What can prevent it from gaining popularity?

17. INTERNET FREEDOM FIGHTERS BUILD A SHADOW WEB

Governments and corporations have more control over the Internet than ever. Now digital activists want to build an alternative network that can never be blocked, filtered or shut down

(original article is in Scientific American, re-published here in the public interest)

By Julian Dibbell

- The Internet was designed to be a decentralized system: every node should connect to many others. This design helped to make the system resistant to censorship or outside attack.
- Yet in practice, most individual users exist at the edges of the network, connected to others only through their Internet service provider (ISP). Block this link, and Internet access disappears.
- An alternative option is beginning to emerge in the form of wireless mesh networks, simple systems that connect end users to one another and automatically route around blocks and censors.
- Yet any mesh network needs to hit a critical mass of users before it functions well; developers must convince potential users to trade off ease of use for added freedom and privacy.

Just after midnight on January 28, 2011, the government of Egypt, rocked by three straight days of massive antiregime protests organized in part through Facebook and other online social networks, did something unprecedented in the history of 21st-century telecommunications: it turned off the Internet. Exactly how it did this remains unclear, but the evidence suggests that five well-placed phone calls – one to each of the country's biggest Internet service providers (ISPs) – may have been all it took. At 12:12 a.m. Cairo time, network routing records show, the leading ISP, Telecom Egypt, began shutting down its customers' connections to the rest of the Internet, and in the course of the next 13 minutes, four other providers followed suit. By 12:40 a.m. the operation was complete. An estimated 93 percent of the Egyptian Internet was now unreachable. When the sun rose the next morning, the protesters made their way to Tahrir Square in almost total digital darkness.

Both strategically and tactically, the Internet blackout accomplished little – the crowds that day were the biggest yet, and in the end, the demonstrators prevailed. But as an object lesson in the Internet's vulnerability to top-down control, the shutdown was alarmingly instructive and perhaps long overdue.

Much has been made of the Internet's ability to resist such control. The network's technological origins, we are sometimes told, lie in the cold war – era quest for a communications infrastructure so robust that even a nuclear attack could not shut it down. Although that is only partly true, it conveys something of the strength inherent in the Internet's elegantly decentralized design. With its multiple, redundant pathways between any two network nodes and its ability to accommodate new nodes on the fly, the TCP/IP protocol that defines the Internet should ensure that it can keep on carrying data no matter how many nodes are blocked and whether it's an atom bomb or a repressive regime that does it. As digital-rights activist John Gilmore once famously said, "The Internet interprets censorship as damage and routes around it."

That is what it was designed to do anyway. And yet if five phone calls can cut off the Internet access of 80 million Egyptians, things have not worked quite that way in practice. The Egyptian cutoff was only the starkest of a growing list of examples that demonstrate how susceptible the Internet can be to top-down control. During the Tunisian revolution the month before, authorities had taken a more targeted approach, blocking only some sites from the national Internet. In the Iranian postelection protests of 2009, Iran's government slowed nationwide Internet traffic rather than stopping it altogether. And for years China's "great firewall" has given the government the ability to block whatever sites it chooses. In Western democracies, consolidation of Internet service providers has put a shrinking number of corporate entities in control of growing shares of Internet traffic, giving companies such as Comcast and AT&T both the incentive and the power to speed traffic served by their own media partners at the expense of competitors.

What happened, and can it be fixed? Can an Internet as dynamically resilient as the one Gilmore idealized – an Internet that structurally resists government and corporate throttles and kill switches – be recovered? A small but dedicated community of digital activists are working on it. Here is what it might look like.

It's a dazzling summer afternoon at the wien-semmering power plant in Vienna, Austria. Aaron Kaplan has spent the past seven minutes caged inside a dark, cramped utility elevator headed for the top of the plant's 200-meter-high exhaust stack, the tallest structure in the city. When Kaplan finally steps out onto the platform at its summit, the surrounding view is a panorama that takes in Alpine foothills to the west, green Slovakian borderlands in the east and the glittering Danube straight below. But Kaplan did not come here for the view. He walks straight to the platform's edge to look instead at four small, weatherized Wi-Fi routers bolted to the guardrail.

These routers form one node in a nonprofit community network called FunkFeuer, of which Kaplan is a co-founder and lead developer. The signals that the routers beam and pick up link them, directly or indirectly, to some 200 similar nodes on rooftops all over greater Vienna, each one owned and maintained by the user who installed it and each contributing its bandwidth to a communal, high-speed Internet connection shared almost as far and wide as Kaplan, from the top of the smokestack, can see.

FunkFeuer is what is known as a wireless mesh network. No fees are charged for connecting to it; all you need is a $150 hardware setup (“a Linksys router in a Tupperware box, basically,” Kaplan says), a roof to put your equipment on and a line-of-sight connection to at least one other node. Direct radio contact with more than a few other nodes isn’t necessary, because each node relies on its immediate neighbors to pass along any data meant for nodes it cannot directly reach. In the network’s early months, soon after Kaplan and his friend Michael Bauer started it in 2003, the total number of nodes was only about a dozen, and this bucket brigade transmission scheme was a sometimes spotty affair: if even one node went down, there was a good chance the remainder could be cut off from one another or, crucially, from the network’s uplink, the one node connecting it to the Internet at large. Keeping the network viable around the clock back then “was a battle,” Kaplan recalls. He and Bauer made frequent house calls to help fix ailing user nodes, including one 2 a.m. rooftop session in the middle of a – 15 degree Celsius snowstorm, made bearable only by the mugs of hot wine ferried over by Kaplan’s wife.

As the local do-it-yourself tech scene learned what FunkFeuer offered, however, the network grew. At somewhere between 30 and 40 nodes, it became self-sustaining. The network’s topology was rich enough that if any one node dropped out, any others that had been relying on it could always find a new path. The network had reached that critical density at which, as Kaplan puts it, “the magic of mesh networking kicks in.”

Mesh networking is a relatively young technology, but the “magic” Kaplan talks about is nothing new: it is the same principle that has long underpinned the Internet’s reputation for infrastructural resilience. Packet-switched store-and-forward routing – in which every computer connected to the network is capable not just of sending and receiving information but of relaying it on behalf of other connected computers – has been a defining architectural feature of the Internet since its conception. It is what creates the profusion of available transmission routes that lets the network simply “route around damage.” It is what makes the Internet, theoretically at least, so hard to kill.

If the reality of the Internet today more closely matched the theory, mesh networks would be superfluous. But in the two decades since the Internet outgrew its academic origins and started becoming the ubiquitous commercial service it is now, the store-and-forward principle has come to play a steadily less meaningful role. The vast majority of new nodes added to the network in this period have been the home and business computers brought online by Internet service providers. And in the ISP’s connection model, the customer’s machine is never a relay point; it’s an end point, a terminal node, configured only to send and receive and only to do so via machines owned by the ISP. The Internet’s explosive growth, in other words, has not added new routes to the network map so much as it has added cul-de-sacs, turning ISPs and other traffic aggregators into focal points of control over the hundreds of millions of nodes they serve. For those nodes there is no routing around the damage if their ISP goes down or shuts them off. Far from keeping the Internet tough to kill, the ISP, in effect, becomes the kill switch.

What mesh networks do, on the other hand, is precisely what an ISP does not: they let the end user’s machine act as a data relay. In less technical terms, they let users stop being merely Internet consumers and start being their own Internet providers. If you want a better sense of what that means, consider how things might have happened on January 28 if Egypt’s citizens communicated not through a few ISPs but by way of mesh networks. At the very least, it would have taken a lot more than five phone calls to shut that network down. Because each user of a mesh network owns and controls his or her own small piece of the network infrastructure, it might have taken as many phone calls as there were users – and much more persuading, for most of those users, than the ISPs’ executives needed.

At 37 years old, sascha meinrath has been a key player in the community mesh-networking scene for about as long as there has been a scene. As a graduate student at the University of Illinois, he helped to start the Champaign-Urbana Community Wireless Network (CUWiN), one of the first such networks in the U.S. Later, he co-organized a post-Katrina volunteer response team that set up an ad hoc mesh network that spanned

60 kilometers of the disaster area, restoring telecommunications in the first weeks after the hurricane. Along the way, he moved to Washington, D.C., intent on starting a community wireless business but instead ending up being “headhunted,” as he puts it, by the New America Foundation, a high-powered think tank that hired Meinrath to generate and oversee technology initiatives. It was there, early last year, that he launched the Commotion wireless project, an open-source wireless mesh-networking venture backed by a $2-million grant from the U.S. State Department.

The near-term goal of the project is to develop technology that “circumvents any kill switch and any sort of central surveillance,” Meinrath says. To illustrate the idea, he and other core Commotion developers put together what has been called a prototype “Internet in a suitcase”: a small, integrated package of wireless communications hardware, suitable for smuggling into a repressive government’s territory. From there, dissidents and activists could provide unblockable Internet coverage. The suitcase system is really just a rough-and-ready assemblage of technologies already well known to mesh-networking enthusiasts. Any sufficiently motivated geek could set one up and keep it working.

The long-term question for Meinrath and his colleagues is, “How do you make it so easy to configure that the other 99.9 percent of nongeek humanity can do it?” Because the more people use a mesh network, the harder it is to kill.

In one way, this is numerically self-evident: a mesh network of 100 nodes takes less effort to shut down, node by node, than a mesh of 1,000 nodes. Perhaps more important, a larger mesh network will tend to contain more links to the broader Internet. These uplinks – the sparsely distributed portal nodes standing as choke points between the mesh and the rest of the Internet – become less of a vulnerability as the mesh gets bigger. With more uplinks safely inside the local mesh, fewer everyday communications face disruption should any one link to the global network get cut. And because any node in the mesh could in principle become an uplink using any external Internet connection it can find (dial-up ISP, tethered mobile phone), more mesh nodes also mean a greater likelihood of quickly restoring contact with the outside world.

Size matters, in a word. Thus, in mesh-networking circles, the open question of mesh networks’ scalability – of just what size they can grow to – has tended to be a pressing one. Whether it is even theoretically possible for mesh networks to absorb significant numbers of nodes without significantly bogging down remains controversial, depending on what kind of numbers count as significant. Just a few years ago some network engineers were arguing that mesh sizes could never grow past the low hundreds of nodes. Yet currently the largest pure-mesh networks have node counts in the low four digits, and dozens of community networks thrive, with the biggest of them using hybrid mesh-and-backbone infrastructures to reach node counts as high as 5,000 (like the Athens Wireless Metropolitan Network in Greece) and even 15,000 (like Guifi.net in and around Barcelona). The doubt that lingers is whether it is humanly possible for mesh networks to grow much bigger, given how most humans feel about dealing with technologies as finicky and complicated as mesh networks.

Unlike most open-source technologies, which tend to downplay the importance of a user-friendly interface, the mesh movement is beginning to realize how critical it is for its equipment to be simple. But if Commotion is not alone in seeking to make mesh networks simpler to use, the key simplification it proposes is a uniquely radical one: instead of making it easier to install and run mesh-node equipment in the user’s home or business, Commotion aims to make it unnecessary. “The notion is that you can repurpose cell phones, laptops, existing wireless routers, et cetera,” Meinrath explains, “and build a network out of what’s already in people’s pockets and book bags.” He calls it a “device as infrastructure” network, and in the version he envisions, adding one more node to the mesh would require all the effort of flipping a switch. “So in essence, on your iPhone or your Android phone, you would push a button and say, yes, join this network,” he says. “It needs to be that level of ease.”

Imagine a world, then, in which mesh networks have finally reached that level – finally cleared the hurdle of mass usability to become, more or less, just another app running in the background. What happens next? Does the low cost of do-it-yourself Internet service squeeze the commercial options out of the market until the last of the ISPs’ hub-and-spoke fiefdoms give way to a single, world-blanketing mesh?

Even the most committed supporters of network decentralization aren’t betting on it. “This type of system, I think, will always be a poor man’s Internet,” says Jonathan Zittrain, a Harvard Law School professor and author of The Future of the Internet: And How to Stop It. Zittrain would be happy to see the mesh approach succeed, but he recognizes it may never match some of the efficiencies of more centrally controlled networks. “There are real benefits to centralization,” he says, “including ease of use.” Ramon Roca, founder of Guifi.net, likewise doubts mesh networks will ever put the ISPs out of business – and for that matter, doubts such networks will ever take much more than 15 percent of the market from them. Even at that low a rate of penetration, however, mesh networks can serve to “sanitize the market,” Roca argues, opening up the Internet to lower-income households that otherwise could not afford it and spurring the dominant ISPs to bring down prices for everybody else.

As welcome as those economic effects might be, the far more important civic effects – mesh networking’s built-in resistances to censorship and surveillance – need a lot more than a 15 percent market share to thrive. And if it is clear that market forces alone are not going to get that number up much higher, then the question is, What will?

Typically, when markets fail to deliver a social good, the first place that gets looked to for a fix is government. In this case particularly, that is not a bad place to start looking. The same mesh network that routes around censorship as if it were damage can just as effectively route around actual damage, which makes mesh networks an ideal communications channel in the face of hurricanes, earthquakes and other natural disasters of the kind that governments are charged with protecting against. Zittrain contends, therefore, that it would be good policy for governments to take an active hand in spreading mesh networks not just among foreign dissidents but among their own citizens. All it might take is a requirement that cell phones sold in the U.S. come equipped with emergency mesh-networking capabilities so that they are ready to turn themselves into relay-capable nodes at the press of a button. From a public policy perspective, Zittrain says, “it’s a no-brainer to build that. And the national security and law-enforcement establishments should generally cheer it on.”

The hitch, of course, is that it is just as easy to picture law-enforcement agencies denouncing any national mesh network as a place for criminals and terrorists to communicate out of earshot of the telephone and ISP companies that facilitate surveillance. Such are the complications of counting on government to support mesh networking when it is governments, often enough, that do the kind of damage mesh networks promise to help fix.

It is doubtful, then, that governments can be relied on to do the job any more than markets can. But Eben Moglen has some thoughts about what might. Moglen is a law professor at Columbia University and for many years has been the lawyer for the Free Software Foundation, a nonprofit group of digital activists. Last February, inspired partly by the news from Tunisia, he announced a project called FreedomBox. He also announced he was seeking start-up money for the project on the crowdsourced funding site Kickstarter, and he went on to raise $60,000 in five days.

As a project, FreedomBox has a number of similarities to Commotion, few of them entirely coincidental (Meinrath has a seat on the FreedomBox Foundation's technical advisory committee). Like Commotion, the project broke ground with an illustrative prototype – in this case, the FreedomBox, a networking device about the size of a small brick that costs "$149, in small quantity, and will ultimately be replaced by a bunch of hardware that is half that cost or less," Moglen says.

Again like Commotion, FreedomBox is not tied to the form of any specific gadget. Rather it's a stack of code that can go into the increasing number of networked CPUs that are piling up in our homes and lives, like "dust bunnies under people's couches," as Moglen puts it. All of these can become the infrastructure of an Internet that "rebalances privacy" and restores the vision of "a decentralized network of peers." There are IP addresses in television set-top boxes, in refrigerators – any of these, Moglen says, could be a FreedomBox. And it is not just about decentralizing the infrastructure. It is about decentralizing data, too. For Moglen, for example, the concentration of user data in cloud services such as Facebook and Google is just as much a threat to privacy and freedom of expression as the concentration of traffic in ISPs. To counteract this trend, FreedomBox will be optimized to run alternative social networks such as Diaspora that store your personal data on your machine, sharing it only with the people you choose via peer-to-peer networks.

Still, the key element in the project, Moglen says, is "the political will that is being displayed by a generation of young people who, because of their dependence on social networking, are increasingly aware of their and other people's vulnerability online." It is this earnestness he is counting on to motivate, in part, the many coders who are contributing labor to the project. It is also the one thing likeliest to push users to adopt the technology. Short of a sustained campaign of techno-activism, Moglen suggests, it's not clear what will ever wake the average user to the broad costs in eroded freedom and privacy that we pay for ease of use and other, more immediately tangible benefits.

"People underestimate the harm being done by the death of privacy pretty much in the same way that they underestimate the extraordinary multiplicative consequences of other ecologically destructive acts," such as littering and polluting, Moglen says. "It's hard for human beings to calculate ecologically. It's not a thing that the primate brain evolved to do."

This suggests that the reinvention of the Internet can never be just a matter of tweaking the technologies. It may require a political movement as broad-based and long-ranged as the environmental movement. If neither government nor markets can lead us there, maybe only a collective change of awareness will do, like the kind of change that the green movement brought about by force of will. Nobody recycled before. Now we do. Nobody uses mesh infrastructure now. Someday we might.

Even then, no single technical measure would be enough to preserve the freedoms that the Internet both evokes and embodies. That's because, ultimately, even the ideal, unkillable Internet can't, on its own, resist the social and economic forces that push to recentralize it. Mesh networking is just one way to help push back. "These mesh networks are good for communities, and the bigger they are, the better," Funkfeuer's Kaplan says. But even a single, worldwide mesh would still be at risk of retracing the evolutionary steps that led to the compromised Internet we have now. "Mesh networking is not a replacement for the Internet. It's just part of it," he says. "There's no place for utopia here."

Part 1 (from 'Just after midnight…' till '…long-term question', tasks)

Task 1

Which paragraph(s):
1. shows that the Internet does not work the way it is supposed to;
2. says that what happened in Egypt should have happened long time ago;
3. explains why the wireless mesh network is not so easy to disable;
4. explains why the early mesh was not very stable;
5. gives examples of where mesh networks can be used; what makes;
6. explains mesh networks especially important nowadays.

Task 2

Say whether the following is true, false or not mentioned:
1. The internet kill helped the government to suppress the demonstrations in Egypt.
2. The Internet was considered to be a very robust structure.

3. Being in theory a very reliable structure the Internet proved actually vulnerable to the outside control.
4. Totalitarian regimes such as China or Iran have always tried to control the Internet.
5. It costs a lot to join a wireless mesh network.
6. The first wireless mesh could easily break down.
7. The Internet development made the problem of network robustness especially urgent.
8. Wireless mesh and the ISPs are two sides of the coin.

Task 3

Answer the following questions:
1. What happened in Egypt?
2. What did the government measures result ikn?
3. Why did the Internet prove so vulnerable though nothing short of a nuclear explosion could destroy it?
4. How can we avoid the situation?
5. What is the difference between the two approaches to the Internet?

Part 2

Task 1

Say whether the following is true, false or not mentioned:
1. The robustness of mesh networks is inverse to the number of nodes.
2. All the nodes in the mesh network are interchangeable.
3. It is still unproved whether a network can consist of a large number of nodes and remain stable.
4. Eventually mesh networks will kill centralized networks.
5. Mesh networks can be as good as ordinary networks but they will never win over 15% of the market as they are too complicated to deploy and use.
6. Governments will never agree to help create a national mesh network.
7. The information stored in social networks or search engines is as dangerous for privacy as the one stored by ISPs.
8. Users do not care much about privacy just as they do not care much about ecology.
9. One day people will understand that their privacy suffers as long as freedom, and do something about it.
10. The mesh network quality is directly proportional to the number of nodes.

Task 2

Answer the following questions:
1. Why is a larger mesh network more reliable?
2. How large can the mesh network be in theory/
3. What prevents them from growing?
4. Do modern smartphones and tablet PCs have the function of forming a mesh network?
5. Do you think mesh networks will squeeze centralized networks out ofc the market? Why? Why not?
6. How can their share be increased?
7. What is the purpose of that?
8. Do you think governments will be willing to help deploy mesh networks? Why? Why not?
9. What ‘s the main idea of the Freedom Box?

Task 3

Which paragraph(s) says that
1. It is not enough to upgrade the equipment to preserve the I-net freedom;
2. Our everyday carry along gadgets can be used to form a mesh network;
3. Centralized networks work better than decentralized ones;
4. Explains why bigger mesh networks are more robust;
5. Deals with the purpose the mesh network can serve;
6. Mentions the threat the I-net as it is now puts its users under;
7. Mentions the problems in the way of creating nationwide mesh networks

18. CONSIDERATE COMPUTING

Digital gadgets demand ever more of our attention with their rude and thoughtless interruptions. Engineers are now testing computers, phones and cars that sense when you're busy and spare you from distraction

By W. Wayt Gibbs

"YOUR BATTERY IS NOW FULLY CHARGED," ANNOUNCED THE LAPTOP COMPUTER to its owner, Donald A. Norman, with enthusiasm – perhaps even a hint of pride? – in its synthetic voice. Norman, a chief advocate of the notion that computers and appliances ought to be programmed with something akin to emotions, might normally have smiled at the statement. Instead he blushed – and no doubt wished that his computer could share his embarrassment. For at that moment. Norman was onstage at a dais, having addressed a conference room of cognitive scientists and computer researchers, and his Powerbook was still plugged into the public address system. Many in the audience chuckled at the automated faux pas and shook their heads.

The moderator, flustered, shot Norman a less than sympathetic look. And yet we've all been there. Our cell phones ring during movies. Telemarketers interrupt our dinners with friends. Our laptops throw up screensavers in the middle of presentations. "You've got mail!" derails our train of thought just as we get in the groove.

To be sure, distractions and multitasking are hardly new to the human condition. "A complicated life, continually interrupted by competing requests for attention, is as old as procreation," laughs Ted Selker of the Massachusetts Institute of Technology Media Lab. But increasingly, it is not just our kids pulling us three ways at once; it is also a relentless barrage of e-mail, alerts, alarms, calls, instant messages and automated notifications, none of them coordinated and all of them oblivious to whether we are busy – or even present. "It's ridiculous that my own computer can't figure out whether I'm in front of it, but a public toilet can," exclaims Roel Vertegaal of Queen's University in Ontario.

Humanity has connected itself through roughly three billion networked telephones, computers, traffic lights – even refrigerators and picture frames – because these things make life more convenient and keep us available to those we care about. So although we could simply turn off the phones, close the e-mail program, and shut the office door when it is time for a meeting or a stretch of concentrated work, we usually don't. We just endure the consequences.

“We take major productivity hits with each interruption,” says Rosalind Picard, a cognitive scientist at the M.I.T. Media Lab. People juggle the myriad demands of work and daily life by maintaining a mental list of tasks to be done.

An interruption of just 15 seconds causes most people to lose part of that to-do list, according to experiments by Gilles 0. Einstein of Furman University.

Numerous studies have shown that when people are unexpectedly interrupted, they not only work less efficiently but also make more mistakes. “It seems to add cumulatively to a feeling of frustration,” Picard reports, and that stress response makes it hard to regain focus. It

isn’t merely a matter of productivity and the pace of life. For pilots, drivers, soldiers and doctors, errors of inattention can be downright dangerous.

“If we could just give our computers and phones some understanding of the limits of human attention and memory, it would make them seem a lot more thoughtful and courteous,” says Eric Horvitz of Microsoft Research. Horvitz, Vertegaal, Selker and Picard are among

a small but growing number of researchers trying to teach computers, phones, cars and other gadgets to behave less like egocentric oafs and more like considerate colleagues.

To do this, the machines need new skills of three kinds: sensing, reasoning and communicating. First a system must sense or infer where its owner is and what he or she is doing. Next it must weigh the value of the messages it wants to convey against the cost of the disruption. Then it has to choose the best mode and time to interject.

Each of these pushes the limits of computer science and raises issues of privacy, complexity or reliability. Nevertheless, “attentive” computing systems have begun appearing in newer Volvos, and IBM has introduced Websphere communications software with a basic busyness sense. Microsoft has been running extensive in-house tests of a much more sophisticated system since 2003. Within a few years, companies may be able to offer every office worker a software version of the personal receptionist that only corner-suite executives enjoy today.

But if such an offer should land in your inbox, be sure to read the fine print before you sign. An attentive system, by definition, is one that is always watching. That considerate computer may come to know more about your work habits than you do.

Minding Your Business

MOST PEOPLE AREN”T AS BUSY as they think they are, which is why we can usually tolerate interruptions from our inconsiderate electronic paraphernalia. James Fogarty and Scott E. Hudson of Carnegie Mellon University recently teamed up with Jennifer Lai of IBM Research to study 10 managers, researchers and interns at work. They videotaped the subjects and periodically had them rate their “interruptibility.” The amount of time the workers spent in leave-me-alone mode varied from person to person and day to day, ranging from 10 to 51 percent. On average, the subjects wanted to work without interruption about one third of the time. In studies of Microsoft employees, Horvitz has similarly found that they typically spend.

more than 65 percent of their day in a state of low attention.

Today’s phones and computers, which naively assume that the user is never too busy to take a call, read an e-mail, or click “OK” on an alert box, thus are probably correct about two thirds of time. (Hudson and Horvitz acknowledge, however, that it is not yet clear how well these figures generalize to other.

jobs.) To be useful, then, considerate systems will have to be more than 65 percent accurate in sensing when their users are near their cognitive limits.

Fortunately, this doesn’t seem to require strapping someone into a heart monitor or a brain scanner. Fogarty and his collaborators have found that simply using a microphone to detect whether anyone is talking within earshot would.

raise accuracy to 76 percent. That is as good as the human judgment of coworkers who viewed videotapes of the subjects and guessed when they were uninterruptible. When Fogarty’s group enhanced the software to detect not only.

conversations but also mouse movement, keyboard activity and the applications.

running on machines, the system’s accuracy climbed to 87 percent for the two managers. Curiously, it rose only to 77 percent for the five scientists, perhaps because they are a chattier bunch.

Bestcom/Enhanced Telephony, a Microsoft prototype based on Horvitz’s work, digs a little deeper into each user’s computer to find clues about what they are up to. Microsoft launched an internal beta test of the system in mid-2003.

By last October, Horvitz says, about 3,800 people were using the system to field their incoming phone calls.

Horvitz himself is one of those testers, and while we talk in his office in Redmond, Wash., Bestcom silently handles one call after another. First it checks whether the caller is listed in his address book, the company directory, or its log

of people he has called recently. Triangulating these sources, it tries to deduce their relationship. Family members, supervisors and people he called earlier today ring through. Others see a message on their computer that he is in a

meeting and won’t be available until 3 P.M. The system scans Horvitz’s and the caller’s calendar and offers to reschedule the call at a time that is open for both. Some callers choose that option; others leave voice mail. E-mail messages get a

similar screening. When Horvitz is out of the office, Bestcom automatically offers to forward selected callers to his cell phone – unless his calendar and other evidence suggest that he is in a meeting.

Most large companies already use computerized phone systems and standard calendar and contact management software, so tapping into those “sensors” should be straightforward. Not all employees will like the idea of having a microphone on all the time in their office, however, nor will everyone want to

expose their datebook to some program they do not ultimately control. Moreover, some managers might he tempted to equate a “state of low attention” with “goofing off” and punish those who seem insufficiently busy.

The researchers seem to appreciate these risks. Hudson argues that an attentive system should nor record audio, keystrokes or the like but simply analyze the data streams and discard them after logging “conversation in progress,” “typing detected,” and so on. “We built a privacy tool into Bestcom from the beginning,” Horvitz emphasizes, “so users can control who is allowed to see the various kinds of information it collects about them.”

Watching the Watcher

AS DIGITAL CAMERAS fall in price, that information may come to include video. With a simple $20 webcam, Horvitz’s software can tell when a person is in view and whether she is alone or in a meeting. Fancier cameras can use the eyes as a window to the mind and perhaps extend the reach of considerate computers into the home.

Vertegaal has filled the Human Media Lab at Queen’s University with everyday appliances that know when you are looking at them. “When I say ‘on,’ the lamp over there doesn’t do anything,” Vertegaal says, pointing over his shoulder. He turns to face the object.

“On,” he says. LEDs mounted on a small circuit board stuck to the lamp Shoot invisible infrared light into his pupils. The light reflects off his retinas, and an infrared camera on the board picks up two bright spots in the image, one

from each eye. A processor does some quick pattern and speech recognition, and the lamp switches on.

Gaze detection can endow quotidian machines with seemingly magical behavior. Vertegaal answers a ringing telephone by looking at it and saying “Hello.” When he stops talking and turns away from the phone, it hangs up. The TV in the lab pauses a DVD or mutes the sound on a broadcast show whenever it notices that there are no longer any eyes watching it. Some of Vertegaal’s students walk around with eye-contact sensors on their hat or glasses. When the wearer enters a conversation, the sensor passes that Information via a wireless link to the cell phone in his pocket, which then

switches from ring mode to vibrate.

Although the technology is steadily improving, gaze detectors are still too expensive, bulky, ugly and unreliable for everyday use. “Eye contact is the most accurate measure of attention that we have – about 80 percent accurate in conversational settings," Vertegaal says. "But it's not perfect by any means."

Attentive appliances are mere parlor tricks, moreover, when they act independently. The real payoff will only come from larger, smarter systems that can both divine the focus of our attention and moderate our conversation with all

our personal machines. Doing that reliably will require a nice bit of reasoning.

Trusting the Black Box

BROADLY SPEAKING, computers can use two techniques – rules or models – to decide when and how to transmit a particular piece of information. Both approaches must face the bugbear of complexity.

If the system is limited to following a few rules, users can predict exactly how it will treat a given message. Many e-mail programs, for example, manage spam by maintaining lists of known spammers and of legitimate contacts. When each e-mail arrives, its sender is compared

against both lists and either deleted or delivered. Such systems are simple and clear – but infamously inaccurate.

Spam filters and network firewalls

improved significantly when they began to rely on statistical models, called Bayesian networks that are built by machine-learning algorithms. The user gives the algorithm many examples of desirable messages and also some counterexamples of undesired traffic. "The software identifies all the variables that influence

the property that you are interested in [for example, not spam], then searches over all feasible relationships among those variables to find the model that is most predictive," Horvitz explains.

Bayesian networks can be eerily accurate. "They use probabilities, so they are wise in the sense that they know that they can't know everything," Horvitz elaborates. "That allows them to capture subtle behaviors that would require thousands of strict rules." In January he

plans to present the results of a field trial of a model trained on 559 past appointments taken from a manager's datebook. When challenged with 100 calendar entries it had never seen, the model correctly predicted whether the manager

would attend the meeting 92 percent of the time. And in four out of every five cases, the model matched the manager's own estimate of the cost of interruption during the meeting.

That sounds impressive, but some experts in the field remain skeptical. Users may have a very low tolerance for a system that erroneously suppresses one out of every 10 important calls. "The more 'attentive' things become, the more unpredictable they are," warns Ben Shneiderman of the University of Maryland. "We have a history in this community of creating ‘smart’ devices that people don’t use because they can’t understand how they operate.”

Indeed, Vertegaal reflects, “artificial intelligence couldn’t deliver the personal secretary, because it was too complicated.” Nevertheless, he adds, “I’m pretty sure we can deliver a receptionist.”

That would be welcome, but will considerate computing really reduce interruptions and boost productivity? At least for certain specialized tasks, the answer is: unquestionably.

Consider Lockheed Martin’s HAIL-SS (Human Alerting and Interruption Logistics-Surface Ship) system. In much the way that Bestcom interposes itself between the phone system and an office worker, HAIL-SS keeps an eye on the sailors operating an Aegis naval weapons system and mediates the many alerts

that Aegis produces. In combat simulations, HAIL-SS cut the number of interruptions by 50 to 80 percent, allowing sailors to handle critical alerts up to twice as quickly. The software lowered the perceived difficulty and stressfulness

of the job by one quarter. The U.S. Navy now plans to deploy HAIL-SS throughout the fleet.

No comparable studies have yet been done in the office environment, however. Even with Bestcom diverting callers to voice mail and squelching e-mail alerts, Horvitz was interrupted 14 times in the course of our five-hour interview. Two fire alarms, a FedEx deliveryman and

numerous colleagues poking their head into the office were merely examples of a large class of disruptions that will never disappear, because they benefit the interrupter.

Vertegaal is optimistic nonetheless. “By opening up these new sources of information about how available someone is, people will naturally adapt and use them to apply existing social rules of etiquette,” he predicts. “So just by virtue of letting people know when you’re busy,

you’ll get fewer interruptions.”

W. Wayt Gibbs is senior writer.

Part 1 (up to ‘Horvits himself’)

Task 1

Find words or expressions meaning the following.

1. a raised platform at the end of a hall, for speakers or important people;
2. similar to;
3. a small mistake in words or behavior;

4. to laugh quietly;
5. to interrupt a chain of reflections;
6. to become attuned to, to get used to;
7. steady and persistent;
8. not aware of;
9. very foolish, absurd;
10. an overwhelming, concentrated outpouring;
11. to bear calmly and patiently, polite and respectful;
12. a stupid and clumsy person;
13. to draw a conclusion.

Task 2

Find sentences in support or against the following:
1. When people are disturbed their performance falls dramatically.
2. A considerate computer may prove to be the Big Brother.
3. With a minor change of software we can make our gadgets more considerate.
4. The IBM research proved that most people would not like to be disturbed during their work.
5. The research showed that the system accuracy depended on the subjects.

Task 3

Answer the following questions.
1. When his notebook interrupted him during a conference Normann was a) annoyed; b) angry; c) confused; d) wished he wasn‘t there; e) was puzzled.
2. How did the audience react?
3. What would you do in the situation?
4. What do numerous interruptions result in?
5. Explain the sentence ‘It seems to add up to a feeling of frustration‘
6. What should be done to prevent numerous gadgets from behaving like idiots?
7. Explalin the sentence ‘They videotaped the subjects and had them rate their interruptability‘
8. Can we say that Horvits came to the same conclusion in his research as Fogarty‘s team did?

Part 2 (from ‘Horvits himself’ up to the end)

Task 1

Find words or expressions meaning the following:
1. sth that worries or upsets;
2. likely;
3. strangely, frighteningly;
4. using;
5. to want to do sth;
6. avoiding work;
7. to get rid of as useless;
8. commonplace;
9. to send another way;
10. to discover or guess as if by magic;
11. to silence.

Task 2

Find words or expressions meaning the following:
1. If such a system is installed, some employees may be accused of being idle.
2. People would feel apprehensive if they had to reveal their personal information to some software they have no authority over.
3. Horvits and his team are oblivious to possible dangers of such software.
4. Horvits is annoyed by the fact that a smart computer cannot recognize his presence while a dumb public convenience can.
5. Computers which can react to your look seem like a miracle.
6. To become practical such systems have to be based on AI.
7. A good example of artificial intelligence model is Bayesian networks.
8. The smarter the systems are the harder it is to say how they will behave.
9. There is no doubt that considerate systems will improve our performance in every sphere of office work. As there will be fewer disruptions.

Task 3

Answer the following questions:
1. Where does the degree of accuracy of considerate computers come from?
2. How can accuracy be boosted?
3. How does Betcom deal with phone calls?

4. What arguments does Horvits give to prove that such systems are safe in terms of privacy?
5. What criteria can computers be guided by to be more considerate?
6. What is the greatest obstacle on the way?
7. Why may users have reservations about considerate systems?
8. Is it correct to suggest that considerate computing will be as useful in offices as it is in the Navy?

19. MORPHWARE

Morphware. Magnetic logic may usher in an era in which computing devices can change instantly from one type of hardware to another. By Reinhold Koch.

Flexibility or performance?

That choice is a constant trade-off for microprocessor designers. General-purpose processors in personal computers execute a broad set of software commands that can cope with any task from graphics to complex calculations. But their flexibility comes at the expense of speed. In contrast, application-specific integrated circuits (ASICs), optimized for a given task, such as the computing required in graphics or sound cards, are very fast but lack adaptability.

Some processors fit a niche between these two types of hardware. Called morphware, they can be reconfigured and optimized for any task. One example – the commercially available field-programmable gate array (FPGA) – consists of large blocks of transistors that perform logic operations and that can be “rewired” by the software. Customization enables FPGAs to accelerate data encryption, automatic military target recognition or data compression by a factor of 10 to 100 – enabling, for instance, dramatically enhanced security or faster target acquisition times as compared with a general-purpose CPU (central processing unit).

FPGAs rely on the ubiquitous transistor-based technology called complementary metal oxide semiconductor (CMOS). They have limitations, however. Changing operations on the fly – converting, say, a calculation of a matrix of numbers to a parallel-processing computation – requires the relatively slow rewiring of connections between large blocks of transistors, not the individual elements (gates) that perform a processor’s logic operations. FPGAs generally take up a large amount of space, resulting in a very low density of circuitry and limiting the number and speed of processing operations.

In the past few years, a number of groups have begun to explore a new type of morphware processor that uses layers of magnetic materials to create reconfigurable logic elements. The advantages of these magnetologic elements are that the information stored does not disappear when external power is shut off and that they do not have to be refreshed while the device is in operation. Unlike CMOS-based systems, the logic is nonvolatile. This stability of magnetic bits explains the key role of magnetic materials in data storage, such as hard disks. In a magnetologic device, nonvolatility of information would also reduce power consumption, and a single elementwould be capable of performing different logic functions that typically require multiple transistors.

From Cell Phone to MP3 Player

MAGNETOLOGIC COULD BRING electronic multitasking to a new level, letting a designer create a cell phone that could later morph into a music player, thereby reducing the need for separate microprocessors in electronic equipment. Because the switching speed of magnetologic gates is fast, switching at billions of cycles per second (gigahertz), this chameleon of processors can alter its functionality many times within the space of even one second.

The operation of magnetologic builds on a technology for storing digital bits known as magnetic random-access memory (MRAM), which is now nearing commercialization. Each unit of MRAM consists of two ferromagnetic metallic alloys separated by a nonmagnetic spacer that ensures that the magnetization of one layer does not affect the other and that the polarity (direction of magnetization) can be shifted independently [see box above]. The memory element represents the value of a digital bit, which depends on whether the magnetization of the upper and lower layers are aligned in parallel or oppose each other. Lower resistance to the flow of electric current occurs when the magnetization of both layers is in parallel – a state that represents, say, a digital “1,” When the polarity of both layers is opposite, the so-called magnetoresistance increases (a “0” state).

To switch the resistance of the MRAM element from low (1) to high (0), or vice versa, an electric current must flow through inputs connected to the memory element. Besides the simple 0 or 1 that it stores in memory, a single MRAM element can be used to represent basic logic functions, such as AND or OR.

Elementary magnetologic gates date back to the early 1960s but were quickly supplanted by silicon microchips. In 2000 William C. Black, Jr., and Bodhisattva Das of Iowa State University published a seminal report on magnetologic based on magnetoresistance. Two years later Siemens Research in Erlangen, Germany, demonstrated experimentally a reconfigurable magnetologic element. Then, in 2003, our group at the Paul Drude Institute in Berlin published a paper that proposed using a simpler implementation for changing the logic states of the various computational elements.

Making a Logic Gate

A MAGNETOLOGIC GATE is very similar to an MRAM cell. It also consists of two magnetic layers separated by a nonmagnetic spacer in which the parallel and antiparallel magnetizations exhibit low and high resistance and provide the logic outputs “1” and “0,” respectively. In general, the magnetoresistance of layered systems is significantly higher than that of systems not built in layers, easing the reading and writing of bits. This property is known as giant magnetoresistance or tunneling magnetoresistance, depending on which type of spacer material is used. Both effects depend on the electrons’ spins (their angular momenta), which are all aligned in the same direction, almost as if the electrons were tiny balls spinning on their axes. These effects are used to “read” the value of a bit.

Changing the orientation of spin is used to “write” a bit – in other words, to change the magnetization from one direction to another. The direction of magnetization of either layer can be reversed by the magnetic field of a current flowing through the input lines. But a number of investigators are examining another method, in which spin exerts a torque that can switch a layer’s magnetization from one direction to another [see “Spintronics,” by David D. Awschalom, Michael E. Flatte and Nitin Samarth; SCIENTIFIC AMERICAN, June 2002].

In the design we put forward at Paul Drude, the magneto-logic gate contains three inputs – A, B and C – each of which is addressed by a current of equal magnitude. Our concept makes use of the fact that a magnetoresistive element, though providing only two output values (a 0 and a 1), can be in four different initial states, two of them parallel and two of them antiparallel, allowing the configuration of distinct logic states. Previous magnetologic designs required more complex circuitry that would employ, for example, input currents of different intensity.

In our design, a logic operation begins by setting the gate polarity in one of these four states by addressing two or three of the input lines. Then, in a second step, the logic operation is performed by activating only the upper two input lines, A and B. A chosen initial state can only be reversed when two or three of the input lines are addressed with the same polarity magnetic field, changing the output value from 1 to 0, or the converse [see box below]. This process has the advantage that the logic state can be reprogrammed with each new operation.

Because the magnetologic gate maintains its assigned polarity in the absence of an external current, a bit is stored without continuous refreshing and can be read out without deleting the information. Thus, the combined logic and storage capability saves not only energy but also time, compared with information processed by conventional CMOS circuitry.

For the AND function, for example, we start from an anti-parallel state with an output of 0. Viewed in cross section, the polarity of the top layer points to the left, whereas the bottom layer points right. Only positive currents that are applied to both inputs A and B – currents that generate a positive magnetic field – can switch the direction of magnetization of the top layer from left to right. The OR gate operates using an analogous method, but the magnetizations of both layers point to the right at the beginning of the procedure. The other two basic logic functions are obtained by switching the bottom layer. All three inputs – A, B and C – are applied to switch the lower layer. The magnetic field needed to switch the polarity of the top layer is less than that for the bottom layer, so the two can be addressed independently. Switching the bottom layer transmutes the output of an AND and OR function into its opposite: NOT AND (NAND) or NOT OR (NOR) [see box above].

The OR and AND functions correspond to Boolean addition and multiplication, respectively. Together with NAND and NOR, they represent a powerful basis for describing even the most complex circuits. By changing the procedure of addressing the inputs, magnetoresistive logic gates can produce even more advanced logic functions. For instance, the XOR gate – key to a critical logic unit called a full adder – differentiates between the same and opposite inputs, yielding an output 1 for any two of the same inputs (0/0 or 1/1) and 0 for opposite inputs (0/1 or 1/0). Two magnetoresistive elements can create the XOR gate as compared with eight to 14 transistors in CMOS technology.

The magnetologic gates can also be employed to construct an entire full adder – the most widely used logic unit in a pro¬cessor. A full adder sums binary inputs A and B plus a carry digit brought forward from a previous calculation. The addition of the three digits produces a new sum as well as a new carry digit. The nonvolatility and the programmability of the magnetologic gates mean that a full adder can be fashioned with only three gates, rather than the 16 transistors with CMOS. The magnetic full adder might become competitive in speed even with the fastest CMOS full adders and boasts superior power efficiency.

Looking Ahead

THE FATE OF MORPHWARE could closely resemble that of commercially announced MRAM cells. The input lines A and B would be arranged in the form of a rectangular grid, a so-called crossbar geometry, similar to that in an MRAM. The magnetoresistive gate elements would sit in the crossing points and be switched only when both input lines are addressed simultaneously. The gates would have to be stacked on top of a template of CMOS transistors that would relay signals indicating when each gate element should begin and stop processing. The transistors in this configuration would also be used to amplify the small currents needed to read a magnetoresistive bit [see box on page 51].

The chameleonlike nature of a morphware processor retains many advantages. Because of the programmability of the logic gates, hardware no longer determines processor capabilities. In CMOS, the logic of a conventional transistor gate is defined by the wiring and is therefore fixed. A magnetic processor constitutes an array of logic gates, each of them programmable individually by the software.

A magnetic chameleon processor therefore needs far fewer logic gates than a conventional processor, in which only a few percent of the hardwired gates are useful for any given task. The programmability also means that newer and better software can easily be implemented, even on older magneto-logic processors. Because the switching speed of magneto-logic gates is fast, billions of cycles per second, a chameleon processor can alter its functions many times within the confine

the output of its last operation – also gives the device a benefit in speed. Although magnetologic is fast, its gigahertz switching time is comparable to that of CMOS processors. But nonvolatility means that a clock is not needed to synchronize the extraction of digital bit values from the storage cells in a computer’s memory, which simplifies and speeds processing. The bits themselves are stored where they are processed. Unlike CMOS, magnetologic does not necessarily have to reduce component size to increase performance – in other words, it bypasses miniaturization. This advantage may appear increasingly attractive as chip manufacturers struggle to make components ever smaller.

Design of a future chameleon processor is still an academic proposition – for now, no one is considering its development outside of the few laboratories that have published papers. Because of its close similarity to MRAM, magnetologic may benefit from engineering work that is addressing problems such as the coupling of magnetic fields between layers in the memories. Similarly, it could suffer if the industry slows development of the technology. Already some companies have hesitated to move ahead with MRAM, estimating that yet another version of random-access memory is unlikely to pull in large revenues. In magnetologic’s early implementation, MRAM itself might function as an elementary processor that could be used in early products. But because only one magnetic layer is switched in MRAM, only two programmable functions could be accessed, either AND/OR or NAND/NOR.

To achieve the full potential of a magnetic chameleon processor, many challenging, but ultimately solvable, problems must be surmounted: First, both magnetic layers need to be switched independently, which is still difficult to do in a real working gate. Also, because the processor is working to full capacity most of the time, it generates pockets of heat locally that could compromise the integrity of the data. So reliability requirements for reading and writing operations are much higher. Engineers must show that magnetologic gates can achieve a lifetime as high as 1016 to 1017 operations, requiring longevity improvements of two or three orders of magnitude.

In the meantime, one mitigating factor is that defective gates can be detected and bypassed when a computer boots up. To optimize magnetologic, new magnetic compounds are needed that are compatible with semiconductors and exhibit a giant magnetoresistance [see “Magnetic Field Nanosensors,” by Stuart A. Solin; SCIENTIFIC AMERICAN, July 2004].

Perhaps one of the most imposing hurdles is to develop a compiler language and new algorithms that take full advantage of the real-time reprogrammability of the logic gates. To bring a magnetic chameleon processor to market will require an interdisciplinary research effort that uses the combined skills of specialists in materials science and technology, hardware design and electronics, computer sciences, and mathematics.

Part 1 (from the beginning up to< Because the magnetologic gate maintains its assigned polarity>)

Task 1

Find words or expressions meaning the following:
1. a compromise or balance between two opposing things;
2. sacrificing;
3. to be without;
4. changes to the taste of a buyer;
5. to increase;
6. the process of locating a guided missile or a satellite so that its orbit can be determined;
7. appearing or existing everywhere;
8. while something is operating;
9. unchangeable, constant;
10. resembling a broad flat stone;
11. to move;
12. decreasing;
13. to guarantee;
14. to influence;
15. to place two objects in a particular position in relation with each other;
16.to take the place of;
17. having a great influence in a particular field;
18. to apply (a force, pressure);
19. a moment of force which produces rotation;
20. to suggest.

Task 2

Find sentences for or against the following:
1. The greater the number of tasks an ordinary processor can perform the more slowly it works.

2. Morphware uses the advantages of both general purpose processors and application – specific integrated circuits.
3. A great disadvantage of magnetologic elements is that they are more power hungry.
4. The data stored by magnetic devices depends on continuous power supply.
5. Magnetologic devices originated in the 20th century and did not catch on because of silicon chips.
6. Magnetologic made it possible to create a Swiss army knife type(all in one) of a device.
7. MRAM and a magnetologic gate are two different names of the same device.
8. The scientific background of a magnetologic gate is electrons‘ angular momenta.
9. The new design takes advantage of the statement that a magnetoresistive element has four different initial states,which makes it more complex.
10. FPGAs can be used to track a rocket or a missile.

Task 3

Find paragraph/paragraphs which deal with
1. disadvantages of FPGAs;
2. the history of magnetic devices;
3. which explains the idea behind magnetic logic;
4. explains what makes the new magnetologic gate so good;
5. explains how new magnetologic devices store a bit;
6. explains how they record a bit.

Task 4

Answer the following questions:
1. What do we sacrifice making our processors more universal?
2. What makes morphware different?
3. Why were researches dissatisfied with FPGAs?
4. Why are magnetologic devices so good?
5. How does a magnetic spacer function?
6. How are 1 and 0 represented?
7. Is there any difference between a MRAM cell and a magnetologic device?
8. What physical phenomenon is behind a magnetologic gate?
9. How is information read and stored?

Part 2 (from Because the magnetologic gate maintains its assigned polarity – up to the end)

Task 1

Find words or expressions meaning the following:
1. to make something stay the same;
2. while on the contrary;
3. each separately in the order mentioned;
4. producing;
5. whole;
6. instead of;
7. to look like;
8. ordinary;
9. to keep something or somebody;
10. as a result
11. to gain;
12. in a related way;
13. a pattern of straight lines or wires crossing each other;
14. to pause before taking a decision;
15. finally;
16. difficult but in an interesting way;
17. as completely as possible;
18. making less serious;
19. to overcome;
20. to show;
21. obstacle

Task 2

Say whether the following is true, false or doesn`t say:
1. In magnetologic devices a bit doesn`t need to be read or written again and again but there is danger that all the information will be destroyed while reading out if we don`t apply an external current to the device
2. The magnetologic gate is more economical and as fast as CMOS devices.
3. Since the magnetologic gate has four initial states, it can use extended Boolean logic and cope with the most difficult problems.
4. Since the logic gates can be programmed the processor specifications do not depend on hardware.
5. As it is the case with CMOS in a magnetic processor each logic processor can be programmed individually.

6. In CMOS processors the clock rate is as big as in magnetologic.
7. Magnetologic does not face the problem of making its components ever smaller.
8. Since some firms are worried about their future profits, they are unwilling to develop MRAM.
9. The only drawback of MRAM is that only two programmable functions can be accessed.
10. This problem can easily be solved.
11. As the data may be damaged, it is necessary to make the process of reading and writing data much more reliable and increase the durability of the gate.
12. The chances that the problem of developing a new compiler language and algorithms will be solved are very slim.
13. The author is sure that this is a most difficult problem.

Task 3

What word does the following refer to?
1. that (para 15, line 12);
2. that (para10, line 13);
3. it (para15, line 20);
4. it (para16, line 7);
5. which (para17, line 4);
6. that (para18, line 5).

Task 4

Answer the following questions:
1. Is there any difference in the way the AN D gate and the OR gate operates?
2. How are NAND and NOR used? (Why do we need them?)
3. What happens when we apply a voltage to the bottom layer?
4. What do we need XOR for?
5. What advantages can a morphware processor offer?
6. Why does a magnetic processor need fewer elements than a transistor one?
7. What makes it faster?
8. Why doesn`t the problem of making components smaller exist in magnetologic devices?
9. Why hasn`t magnetologic gained wide recognition?
10. How can all the unique properties be taken advantage of?
11. What`s the main obstacle in the way of fully using the potential of a magnetic processor?
12. Why is it called a chameleon processor do you think?

20. TO INVENT A QUANTUM INTERNET

The physicist and computer scientist Stephanie Wehner is planning and designing the next internet – a quantum one

By Natalie Wolchover, Quanta Magazine on September 28, 2019

The first data ever transmitted over Arpanet, the precursor of the internet, blipped from a computer at the University of California, Los Angeles to one at the Stanford Research Institute in Palo Alto on Oct. 29, 1969.

That evening, the team at UCLA got on the phone with the SRI team and began typing “LOGIN.” “We typed the L and we asked, ‘Did you get the L?’” the UCLA computer scientist Leonard Kleinrock recently recalled. “Yep’ came the reply from SRI. We typed the O and asked, ‘Did you get the O?’ ‘Yep.’ We typed the G and asked, ‘Did you get the G?’ Crash! The SRI host had crashed. Thus was the first message that launched the revolution we now call the internet.”

The ability of networks to transmit data – as well as their tendency to crash, or otherwise behave unpredictably – has always fascinated Stephanie Wehner. “On a single computer, things will happen nice and sequentially,” said Wehner, a physicist and computer scientist at Delft University of Technology. “On a network, many unexpected things can happen.” This is true in two senses: Programs on connected computers interfere with one another, with surprising effects. And users of networks get creative. With the internet, Wehner noted, initially “people thought we would use it to send around some files.”

Wehner first got online around 1992, a few years before it was easy to do so. A teenager in Germany at the time and already a deft computer programmer, she soon became a hacker on the fledgling internet. At 20, she got a job as a “good” hacker, sussing out network vulnerabilities on behalf of an internet provider. Then she grew bored with hacking and sought a deeper understanding of information transmission and networks.

Wehner is now one of the intellectual leaders of the effort to create a new kind of internet from scratch. She is working to design the “quantum internet,” a network that would transmit – instead of classical bits with values of either 0 or 1 – quantum bits in which both possibilities, 0 and 1, coexist. These “qubits” might be made of photons that are in a combination of two different polarizations. The ability to send qubits from one place to another over fiber-optic cables might not transform society as thoroughly as the classical internet, but it would once again revolutionize many aspects of science and culture, from security to computing to astronomy.

Wehner is the coordinator of the Quantum Internet Alliance, a European Union initiative to build a network for transmitting quantum information throughout the continent. In a paper in Science last October, she and two co-authors laid out a sixstage plan for realizing the quantum internet, where each developmental stage will support new algorithms and applications. The first stage is already underway, with the construction of a demonstration quantum network that will connect four cities in the Netherlands – a kind of Arpanet analogue. Tracy Northup, a member of the Quantum Internet Alliance based at the University of Innsbruck, praised "the breadth of Stephanie's vision, and her commitment to building the kind of large-scale structures that will make it happen."

After quitting hacking, Wehner went to university in the Netherlands to study computer science and physics. She heard the quantum information theorist John Preskill give a talk in Leiden describing the advantages of quantum bits for communication. A few years later, after earning her doctorate, she left classical bits behind and joined Preskill's group at the California Institute of Technology as a postdoc.

At Caltech, in addition to proving several notable theorems about quantum information, quantum cryptography and the nature of quantum mechanics itself, Wehner emerged as "a natural leader," Preskill said, who "was often the glue that bound people together." In 2014, after a professorship in Singapore, she moved to Delft, where she began collaborating with experimentalists to lay the groundwork for the quantum internet.

Quanta Magazine spoke with Wehner over two days in August. The interview has been condensed and edited for clarity.

The quantum internet is a network for transmitting qubits between distant locations. Why do we need to do that?

The idea is not to replace the internet we have today but really to add new and special functionality. There are all kinds of applications of quantum networks that will be discovered in the future, but we already know quite a number of them. Of course the most famous application is secure communication: the fact that one can use quantum communication to perform what is called quantum key distribution, where the security holds even if the attacker has a quantum computer. A quantum computer would be able to break a lot of the security protocols that exist today.

What makes quantum keys so secure?

A good way to understand what a quantum internet can do is to think about "quantum entanglement," a special property that two quantum bits can have that makes all of this possible. The first property of entanglement is that it's "maximally coordinated": I would have a quantum bit here and you would have a quantum bit in New York, and we would use the quantum internet to entangle these two qubits. And then, if I make a measurement on my qubit here and you make the same measurement in New York, we will always get the same outcome even though the outcome wasn't determined ahead of time. So you can intuitively think that a quantum internet is very good for tasks that require coordination, due to that first property of quantum entanglement.

Now, given that this is so maximally coordinated, you might say, “Hey, wouldn’t it be great if this entanglement could be shared with hundreds of people?” But that’s actually not possible. So the second property of entanglement is that it’s inherently private. If my qubit here is entangled with your qubit in New York, then we know that nothing else can have any share of that entanglement. And this is the reason why quantum communication is so good for problems that require security.

As one of the simplest applications of quantum communication, quantum key distribution could be available as soon as the early 2020s on the demonstration network you’re building. What are some of the more advanced applications that will become possible later?

New kinds of remote computing will become possible. Say you have a proprietary material design and you want to test its properties in a simulation. A quantum computer promises to be much better at that than a classical computer. But you can imagine that not everybody in the world will have a large quantum computer in their living room anytime soon – possibly not in our lifetime. One way of doing that is you send your material design to me, and I run a simulation for you on my quantum computer and tell you the outcome. That’s great, but now I also know your proprietary material design. So one thing the quantum network makes possible is that you can use a very simple quantum device – in fact, it can make only one qubit at a time – and the quantum network can transfer qubits from your device to my powerful quantum computer. And you can use that quantum computer in such a way that it cannot learn what your material design is while performing the computation.

To give another example, people have also shown that entanglement enables more accurate clock synchronization between two places, which will have a lot of applications. A quantum internet could also be used to make a better telescope, basically by combining distant telescopes. The states of the light particles coming into telescope 1 are teleported, using quantum entanglement, to telescope 2, and then they’re combined with the light of telescope 2.

You’re also working on simulating the future quantum internet. Why is that necessary?

With this very extensive simulation platform we’ve recently built, which is now running on a supercomputer, we can explore different quantum network configurations and gain an understanding of properties which are very difficult to predict analytically. This way we hope to find a scalable design that can enable quantum communication across all of Europe.

The unpredictability of networks is something that has always fascinated me. Computers are interesting, but what I really care about is transmitting data from one point to another. This is the reason why I got into hacking, and why I got interested in the classical internet and gaining access to it in the first place. It’s fundamentally really hard to get a handle on what happens in a network, because there are so many uncharacterized things. For example, if you want to send a message, you cannot predict exactly how long it might take. The message might be lost. A computer might crash. It might go too slow; it might corrupt the data. It might have changed the protocol in unexpected ways because it’s an old version or a new version or a malicious version.

Were you a bad hacker before you became a good hacker?

This is not a thing that one can say in interviews! I think the world was a nicer place back then. But I don’t confess to anything.

Why did you decide to quit hacking and become a scientist?

I know that hacking sounds super exciting, but I had already done it for some time. Of course one improves methods, but it’s all a little bit more of the same. I got bored and decided to explore some new adventures. And then I discovered quantum information theory and that was super fascinating.

One theorem you went on to prove about quantum information is the noisy storage theorem. What’s that, and what are the implications for quantum communication?

Noisy storage is about cryptography with a physical assumption. In the classical world, one often makes a computational assumption. For example, you assume that it’s difficult to determine the prime factors of large numbers, and if that assumption is true, then my protocol is secure. These security proofs are nice and they’re everywhere, but one should realize that they may be invalidated later. If at any future point someone invents a smart procedure to solve the computational problem that your security is based on, security can be retroactively broken. For instance, when we have quantum computers, they will be able to factor large numbers, and so security based on factoring will be broken. If someone records your messages today, then they may be decrypted later.

The noisy storage work was about: Can we make a physical assumption that can’t be retroactively broken? The physical assumption is that it’s difficult to store a lot of quantum states without noise, which only needs to be true in a very short time frame. If I make the assumption that right now you can only store up to 1 million noisy qubits, then I can treat my protocol parameters to increase security by sending more information than those million noisy qubits can capture. This is nice because if tomorrow you go and buy quantum memory that has 2 million qubits, that’s too late; the information has already been sent securely.

That would allow us to implement all kinds of protocols in quantum communication. Say two people want to compare each other’s passwords without ever giving them away. It’s not like what we do now, when you use an ATM and punch in your PIN there – instead, I’m going to punch in the PIN on my own device, and it will never be leaked to the ATM. That protocol becomes possible with the noisy storage assumption.

Is the pursuit of the quantum internet likely to foster fundamental insights about the laws of nature – a sort of learning-by-doing approach to science?

There’s sometimes a judgment in the sciences that some questions are fundamental and some questions are mundane. I think bringing something into the real world that people can actually use is never mundane. It is extremely hard. There’s this absolutely mind-blowing jump from, “I have this great idea; let’s discuss it on the whiteboard,” to the cellphone that I’m currently using to talk to you. With the quantum internet, we are trying to do this from scratch. From zero. From an early-stage experiment in the lab to this network that we’re trying to set up in the Netherlands, to something that’s outside the lab, that works over distance, that can be used by people, that they can play around with, then by people who don’t need to know physics in order to do it. If one part of the system already existed, we could say, “Now we’re going to improve that.” But the step from zero to the first version is very large.

In doing this, I think we will get a more fundamental understanding in several areas. We will learn more about the physics by making these networks possible because currently we don’t know exactly how to do it. We’re still trying out different kinds of nodes and quantum repeaters, devices that relay entanglement across large distances. And in the domain of computer science, we will learn an entirely new way to program and control such networks due to fundamental differences from classical communication.

But I also think that using such a network, we gain information about creativity and social sciences – about how, in fact, people will go and use these networks. If you look at the classical internet, people thought we would use it to send around some files. That’s great. But people have gotten more creative.

I gather that it’s hard to lay out a timeline for all this, but in your lifetime do you hope to see what you would legitimately describe as a quantum internet?

I would be optimistic about that, yes.

Part 1 (up to ‘To give another example’)

Task 1

Find words / expressions meaning the following:

1. Immature or underdeveloped;

2. skilful and quick in one's movements;
3. to realize or discover something, or to find out the things that you need to know about someone or something;
4. weaknesses in a computer system;
5. in the interests of a person;
6. from the very beginning;
7. to arrange or prepare;
8. having started and in progress; being done or carried out;
9. the hard work or loyalty that someone gives to activity;
10. result;
11. in advance;
12. basically.

Task 2

Say whether the following is true, false or not mentioned:

1. What is all right for one computer may bring strange results when we deal with a computer network.
2. Some programmes in a computer network run better than others.
3. When she was a teenager Wehner was already an experienced hacker who’d hacked into Dutch
banks and universities.
4. When she grew older, she was responsible for finding loopholes in computer systems.
5. The use of fiber optics to send qubits between two places will affect our everyday life greatly just as the Internet we have now did.
6. Her interview is printed here as is.
7. The quantum internet is supposed to extend the classical internet, not replace it.
8. In her interview Wehner predicts that in 10-20 years everybody will be able to access a quantum internet using their mobiles.
9. Quantum entanglement guarantees a very reliable security
10. Since quantum entanglement cannot be shared, it is good only for point to point communication and cannot be applied to multimode networks.

Task 3

Answer the following questions:

1. What did the internet originate from?
2. What has always aroused Wehner’s interest and curiosity?

3. Why do computer networks behave unpredictably?
4. How did she apply her skills as a programmer in her teens and later?
5. Why did she give up her job?
6. What is the difference between ordinary bits and quantum bits?
7. Does she want to change the classical internet for the quantum one? Why? Why not?
8. Why is quantum communication so secure?
9. How can the quantum internet be used in future?

Part 2 (from ’To give another example’ up to the end)

Task 1

Find words/ expressions meaning the following:
1. covering or affecting a large area;
2. to get;
3. to understand;
4. to attract the strong attention and interest of;
5. hypothesis, suggestion;
6. understanding;
7. ordinary;
8. from the very beginning;
9. to establish;
10. legally, properly.

Task 2

Say whether the following is true, false or not mentioned:
1. Quantum entanglement could contribute to astronomy.
2. Wehner and her colleagues have already created a prototype of a quantum internet and are now testing it using quantum supercomputers.
3. She has always been interested in a bizarre behavior of computer networks and now she finds it easy to understand the processes going on there.
4. She finds it difficult to predict which technology will come first – a widely adopted quantum internet or useful quantum computers
5. She admits that she was a bad hacker.
6. She thinks that quantum information theory is much more exciting than hacking and that’s the reason she took it up.

7. In contrast to classical cryptography based on factors of large numbers , which can be found by quantum computers , quantum codes cannot be broken because of the noisy storage.
8. She still thinks that even in quantum communication one should be extremely careful about sending sensitive information.
9. She believes quantum communication will result in a new way of programming because of fundamental distinctions between it and the classical communication.
10. She considers when the technology is there people will not notice whether they surf the classical internet or the quantum internet, nor will it matter to them

Task 3

Answer the following questions:
1. What caused Wehner's interest in computer networks?
2. Why are they hard to understand?
3. How does traditional cryptography work?
4. What is the main idea of the noisy storage theorem?
5. How does she make her point to prove quantum codes cannot be retroactively broken?
6. Does she think that the quantum internet will give us a profound knowledge of the laws of nature? Why? Why not?
7. What is she doing to send quantum entanglement over long distances?
8. How will the quantum internet help us understand the world?

21. CREEPY MUSIC AND SOVIET SPYCRAFT: THE AMAZING LIFE OF LEON THEREMIN

The godfather of electronic music was also a darling of the New York social scene, a gulag prisoner and the man behind one of the most ingenious spy devices ever created.

By Nathaniel Scharping October 31, 2019 10:00 PM

Imagine a UFO descending from the heavens, its round disk pale against the night sky. What sound does it make? You’re likely imagining a keening whine in your head, like the howling of a haunted wind or the moans of a high-pitched ghost.

That’s the sound of the theremin, a musical instrument invented nearly a century ago. It was one of the first electronic musical instruments, and the first to be mass-produced. The theremin’s ethereal tones made it ubiquitous in science fiction film scores during the middle of the 20th century.

But the curious instrument was actually invented decades earlier, in 1920, by a Russian scientist named Lev Sergeyevich Termen. As a young man working at the Physical Technical Institute in Petrograd, he noticed that something odd happened when he hooked up audio circuits to an electrical device called an oscillator in a certain configuration. The oscillator produced an audible tone when he held his hands near it, and he could shift the tone just by waving his hands back and forth.

A classically trained cellist, Termen was immediately intrigued. Where other engineers may have seen a quirk of capacitators and circuits, he saw the opportunity to summon symphonies from the invisible.

Termen showed the device to his superiors and delivered the first concert with his device soon after. He followed with a private demonstration for Lenin in 1922, who was apparently intrigued by the strange device. The theremin – or etherphone, as it was originally called – had already become Termen’s calling card.

The instrument became the forerunner of modern synthesizers, and had an indelible influence on the soundscapes of classic science fiction. Echoes of the theremin’s futuristic sounds appear everywhere, from the classic synth tones of ’90s-era G-funk to U.K. house music.

But all that came later. At the time of its creation, nearly 100 years ago, the theremin marked a seminal moment in the life of its young inventor. It was the beginning of a transcontinental voyage for Lev Termen, one that would make him a millionaire and a prisoner, a celebrated musician and a Soviet spy.

Cello in a Dense Fog

Termen, known also as Leon Theremin, was born in 1896 in St. Petersburg, Russia. A bright child, he took an interest in physics and astronomy from a young age – reportedly discovering a new star at the age of 15.

Termen enrolled in university classes at St. Petersburg University, as Albert Glinsky writes in his biography of Termen, Theremin: Ether Music and Espionage. But his studies were disrupted by World War I, for which he was conscripted as a radio technician. After the war ended, he began work in earnest in the promising new world of electrical devices, leading quickly to the invention of the theremin.

The instrument's genesis was the product of a lingering dissatisfaction with the musical instruments of the time, Termen said. The bows, reeds and keys of the instruments of the day could only produce so many sounds – he wanted more.

"I realized there was a gap between music itself and its mechanical production, and I wanted to unite both of them," Termen said of his invention in a 1989 interview. "I became interested in bringing about progress in music, so that there would be more musical resources. I was not satisfied with the mechanical instruments in existence."

The theremin doesn't look like an instrument. It's nothing more than a box with two wires sticking out of it. But to people at the time, the sounds it made, summoned by the simple act of waving two hands near its antennae, were marvelous.

Descriptions of the theremin's curious timbre are varied and expressive, though Harold C. Schonberg, then chief music critic for The New York Times, may have put it best in a 1967 profile. The device sounds something like "a cello lost in a dense fog and crying because it does not know how to get home," he wrote, "not unlike an eerie, throbbing voice."

In the years after the theremin's invention in the early 1920s, at a time when electricity and devices that harnessed it were a source of constant fascination, Termen's instrument must have seemed plucked from the future. The young scientist toured Russia, and eventually Europe, with his new device, giving concerts and demonstrations. His travels culminated with a move to New York City in 1927, where Termen and his instrument quickly became celebrities among the city's artistic elite.

'Ether Music' Device

Soon after moving to the U.S. Termen was ensconced in a large house on 54th Street in New York, where he had a studio, entertaining musicians, scientists and more. Einstein was a guest, and, in Termen's telling, maintained a studio there to work on concepts pairing geometry with music theory.

Just a year later, the electronics company RCA acquired the patent for the theremin, with the plan of mass-producing it for audiences worldwide. Because it required no actual contact, they assumed the device would be easy to learn to play – though later evidence would suggest otherwise.

“Anyone who is able to hum a tune, sing or whistle is likely to play the RCA theremin as well as a trained musician,” an RCA executive, quoted in The New York Times, said of the item, which cost $175. They called it an “ether music” device.

In fact, if you were a fan of the orchestra in New York City at the time, you were probably fairly familiar with the theremin. Thereminists were popping up in orchestras around the city, and well-known conductor Leopold Stokowski planned to write them into popular pieces of music. In 1929, Termen and three other thereminists played at Carnegie Hall, performing works by Chopin, Tchaikovsky and Bach, among others.

He also sought news ways of pushing the boundaries of musical instrumentation. Termen introduced a rudimentary drum machine, the rhythmicon, in 1931. He also created a kind of full-body theremin, called the terpsitone. Where a theremin responded to hand movements, his new creation would create music in response to a musician moving their entire body in and around the device. Termen foresaw an innovative pairing of dance and music, allowing a performer’s expressive movements to be translated into a song of their own.

Though he built a prototype, Termen never found much of an audience for the instrument. What he did find, however, was romance. A dancer named Lavinia Williams, from the American Negro Ballet, had been working with him in his studio, and Termen was smitten. They were eventually married – something that may have turned away potential business partners, the BBC reports, due to the fact that Williams was African-American.

Along with a new wife and an expanding social circle, Termen continued inventing. He created an electronic crib alarm in the wake of the Charles Lindbergh baby scandal, and won a contract to produce a metal detector for Alcatraz (though it never panned out). He was at times a reported millionaire, though debts hounded him constantly – Termen’s capacious intellect did not seem to encompass the world of business.

But his happiness in America was to be short-lived. In 1938, under mysterious circumstances, Termen returned abruptly to Russia, smuggled aboard a Soviet ship using an assumed identity. To his friends and colleagues in New York, he seemingly vanished for almost three decades. Williams, his wife, never saw him again.

The reasons for his departure remain murky and varied. Initial speculation held that he had been kidnapped by the Soviets and violently repatriated in the midst of Russia’s burgeoning involvement in World War II. Later reports suggested that he may simply have been fleeing his creditors in the U.S. Decades later, Termen insisted that his departure was motivated solely by patriotism. As Russia inched closer to war, he wanted to be there to help.

Whatever the reasons, Termen would soon find himself implicated as a traitor in Russia, perhaps because of his time in America. The one-time socialite was sentenced to hard labor in the country's gulag system, which was often a death sentence. His time in the Soviet prisons would stretch for decades, stranding him oceans away from the life he had once lived in New York. But it would also be a kind of rebirth for the brilliant inventor – one that would tip his legacy into infamy.

Spycraft, and a Forerunner to RFID

Life in the Soviet gulags was relentlessly brutal. Prisoners did hard labor, often until their bodies wore down and they died. Though estimates vary, some put mortality rates as high as 20 percent during the system's harshest years. It was hardly a place for a scientist, to say nothing of a man accustomed to the luxuries of the upper crust.

But Termen appears to have made the best of it. Originally assigned to a labor crew, he was soon made supervisor of the workers. And less than a year into his stay, he was brought back to Moscow to join a system of secret laboratories called sharashka, along with other top scientists. There, he began inventing again.

His creations included a system code-named BURAN, which used an infrared beam to pick up the vibrations that sound waves create on a pane of glass. It could be used to listen covertly to conversations inside buildings without risk of being detected. The device was put to use against the U.S., France and Britain during the Cold War, and even used to spy on Stalin himself.

The Thing Spy Device

Termen's most well-known invention during his time in the sharashka, however, was a device known simply as "The Thing." It was a listening device of such simplicity and ingenuity that it would go undetected for seven years in the office of the U.S. ambassador to Russia, transmitting sensitive diplomatic information to the Russians and greatly embarrassing the U.S. upon its discovery.

The spy device was hidden inside a carved wooden Great Seal of the United States, given to the U.S. ambassador by a group of schoolchildren in 1945. It hung proudly in the ambassador's office until 1952, when a British radio operator intercepted its transmissions and "The Thing" was uncovered.

The bug was a simple cavity resonator and circuit attached to an antenna that would only pick up signals when an electromagnetic signal of the correct frequency was aimed at it. Soviet agents outside the embassy only had to aim a radio beam through the windows, and the device would transmit back the voices inside.

It took the CIA years to successfully replicate the spying device, today heralded as a forerunner to modern radio frequency identification – or RFID – technology. The passive transmitters in our keycards, credit cards and more rely on the same principle as Termen's Cold War-era listening bug.

Electricity is Not for Music

Termen was released from the sharashka laboratory in 1947, though he seems, if anything, to have missed it.

"It turned out that when I was free it was much more difficult to work in the lab," he said years later.

Perhaps longing for a return to a life unburdened by anything but science, he asked the KGB to hire him after his release. Termen went on to work in secretive government labs, and for years likely dedicated himself purely to research, though little is known about his activities during this time.

In the early 1960s, Termen was officially cleared of the charges that had put him in the sharashka and allowed to return to a more public life. He took a position at the Moscow State Tchaikovsky Conservatory, where he returned to the experiments with electronic musical instruments that had captivated him as a young man.

His appointment there was to be short-lived, unfortunately. The New York Times published a short profile of him and his experiments in 1967 (the one calling the theremin a "cello lost in a dense fog"). It was the first time many acquaintances in New York had heard from him since he had left. But in Moscow the piece didn't go over well: The conservatory decided his work didn't fit with their mission and closed his lab down.

"Electricity is not good for music; electricity is to be used for electrocution," Termen remembers being told.

Though he spent much of his later life in relative obscurity, a more hopeful coda to his long, tangled life did emerge. A trip to a European music festival in 1989, and a long-overdue return to America in 1991, reintroduced Termen and his inventions to the world. In 1990, well into his ninth decade, Termen performed at the Electronic Music Festival in Stockholm. A documentary on his life followed in 1993, airing two days before his death at 97.

The Theremin's Legacy

Today, Termen remains best known for the instrument that bears his name. Theremins have left an indelible sonic fingerprint on popular culture, though their use has faded today. The most well-known touchstone for the instrument likely remains the Beach Boys' 1966 hit "Good Vibrations." (Though that instrument is not technically a theremin, but a variation known as an electro-theremin.) Five decades later, modern synthesizers can produce a far greater range of sounds and are far more easily controlled.

But the theremin remains just one facet of Lev Termen's prodigious output. Throughout the course of his long life, as he moved between countries and political regimes, freedom and imprisonment, there was one constant: He never stopped inventing. His experiments and irrepressible curiosity led him to multiple technical breakthroughs, any of which would be impressive in its own right. It simply came as a byproduct that they also made him both a pioneering musician and an antagonist to the U.S. government.

Part 1 (up to ‘Though he built a prototype’)

Task 1

Find words /expressions meaning the following:

1. present, appearing, or found everywhere;
2. to connect;
3. a circuit or instrument for producing voltage of a required frequency;
4. something unusual or interesting that happens by chance;
5. permanent, unforgettable;
6. strongly influencing later developments;
7. to interrupt, interfere with;
8. lasting for a long time;
9. to cause
10. to bring something under control and use it;
11. to buy or obtain.

Task 2

Say whether the following is true, false or is not mentioned:

1. Theremin produced eerie sounds good for films about aliens or imitating a howling wind.
2. Its effect was first noticed after connecting sonic elements to an oscillator.
3. Originally the device was meant to measure gas density in a chamber.
4. Theremin’s accidental discovery was that the electromagnetic field around an antenna could be affected by merely moving your body into that field.
5. Being a good musician Termen immediately understood the importance of his discovery.
6. What he actually created was the first synthersizer.
7. As he didn’t get recognition in Soviet Russia, Termen sold his invention to America where its mass production started.
8. The sounds of the existing instruments were not enough for him.
9. As the instrument didn’t need any physical contact, it was very easy to play.
10. The instrument became so popular that Leopold Stakovsky, the famous conductor, wrote music for it.

Task 3

Answer the following questions:

1. Why was the instrument so good for science fiction films?
2. When did it appear?
3. Can we say that Termen thought about creating a new instrument for a long time and finally made it? Why? Why not?
4. Why did he pay attention to the effect?
5. What made him give up the university?
6. What was the reason for his dislike for the existing musical instruments?
7. How can its sound be described?
8. What's the difference between the terpsitone and theremin?
9. What was so innovative about the terpsirtone?

Part 2 (from 'Though he built a prototype' up to the end)

Task 1

Find words /expressions meaning the following:

1. to be successful, turn out well'
2. capable of holding much;
3. suddenly;
4. participation;
5. to show (someone) to be involved in a crime, link;
6. only just;
7. let alone;
8. used to;
9. together with;
10. to catch;
11. to wish;
12. the state of being unknown;
13. mixed-up, messy
14. to weaken;
15. not able to be controlled or restrained

Task 2

Say whether the following is true, false or is not mentioned.

1. Termen was both a talented inventor and a successful businessman.

2. After several years of his life in America he was abducted by secret services and taken back to Russia.
3. In Russia he was suspected of treason because of his life in America, arrested and sent to a labour camp.
4. Even in those hard conditions he continued to invent and created a new alarm system.
5. He seems to have been lucky and after a year and a half in the labour camp he was taken to Moscow to work for a secret laboratory.
6. In the sharashka he invented a device which could detect vibrations of window glass allowing an outside observer to listen to all conversations in the room.
7. He also created a bug which worked as a passive transmitter.
8. He thought of the time spent in the sharashka as of the happiest time in his life.
9. After being cleared of all the charges he found a job in the Moscow Conservatory which took a great interest in his electronic instruments.
10. Only after his return to America in the early 90s did he become world famous.
11. Theremins affected greatly popular culture but now they are not so popular as they used to be.
12. Even now theremin’s range of sounds exceeds that of modern synthesizers though they arde much easier to control.

Task 3

Answer the following questions:

1. Why did Thermen emigrate?
2. Can we say that his invention of a metal detector for Alkatraz was a great success? Why? Why not?
3. How did he explain his return to Russia?
4. What happened to him in Russia?
5. What was he charged with?
6. Did he enjoy his life in the sharashka? Why? Why not?
7. What did he invent there?
8. What was the bug in the American embassy based on?
9. Why did the Moscow Conservatory ignore his instruments and closed his lab?
10. What drove him to invent again and again?

22. STORING DATA IN EVERYDAY OBJECTS

Summary:

Researchers have discovered a new method for turning nearly any object into a data storage unit. This makes it possible to save extensive data in, say, shirt buttons, water bottles or even the lenses of glasses, and then retrieve it years later. The technique also allows users to hide information and store it for later generations. It uses DNA as the storage medium.

Living beings contain their own assembly and operating instructions in the form of DNA. That's not the case with inanimate objects: anyone wishing to 3D print an object also requires a set of instructions. If they then choose to print that same object again years later, they need access to the original digital information. The object itself does not store the printing instructions.

Researchers at ETH Zurich have now collaborated with an Israeli scientist to develop a means of storing extensive information in almost any object. «With this method, we can integrate 3D-printing instructions into an object, so that after decades or even centuries, it will be possible to obtain those instructions directly from the object itself», explains Robert Grass, Professor at the Department of Chemistry and Applied Biosciences. The way of storing this information is the same as for living things: in DNA molecules.

«DNA of Things»

Several developments of the past few years have made this advance possible. One of them is Grass's method for marking products with a DNA «barcode» embedded in miniscule glass beads. These nanobeads have various uses; for example, as tracers for geological tests, or as markers for high-quality foodstuffs, thus distinguishing them from counterfeits. The barcode is relatively short: just a 100-bit code (100 places filled with «0»s or «1»s). This technology has now been commercialised by ETH spin-off Haelixa.

At the same time, it has become possible to store enormous data volumes in DNA. Grass's colleague Yaniv Erlich, an Israeli computer scientist, developed a method that theoretically makes it possible to store 215,000 terabytes of data in a single gram of DNA. And Grass himself was able to store an entire music album in DNA – the equivalent of 15 megabytes of data.

The two scientists have now wedded these inventions into a new form of data storage, as they report in the journal Nature Biotechnology. They call the storage form «DNA of Things,» a takeoff on the Internet of Things, in which objects are connected with information via the internet.

Comparable to biology

As a use case, the researchers 3D printed a rabbit out of plastic, which contains the instructions (about 100 kilobytes' worth of data) for printing the object. The researchers achieved this by adding tiny glass beads containing DNA to the plastic. «Just like real rabbits, our rabbit also carries its own blueprint» Grass says.

And just like in biology, this new technological method retains the information over several generations – a feature the scientists demonstrated by retrieving the printing instructions from a small part of the rabbit and using them to print a whole new one. They were able to repeat this process five times, essentially creating the «great-great-great-grandchild» of the original rabbit.

«All other known forms of storage have a fixed geometry: a hard drive has to look like a hard drive, a CD like a CD. You can't change the form without losing information,» Erlich says. «DNA is currently the only data storage medium that can also exist as a liquid, which allows us to insert it into objects of any shape»

Hiding information

A further application of the technology would be to conceal information in everyday objects, a technique experts refer to as steganography. To showcase this application, the scientists turned to history: among the scant documents that attest to life in the Warsaw Ghetto during World War II is a secret archive, which was assembled by a Jewish historian and ghetto resident at that time and hidden from Hitler's troops in milk cans. Today, this archive is listed on UNESCO's Memory of the World Register.

Grass, Erlich and their colleagues used the technology to store a short film about this archive (1.4 megabytes) in glass beads, which they then poured into the lenses of ordinary glasses. «It would be no problem to take a pair of glasses like this through airport security and thus transport information from one place to another undetected,» Erlich says. In theory, it should be possible to hide the glass beads in any plastic objects that do not reach too high a temperature during the manufacturing process. Such plastics include epoxides, polyester, polyurethane and silicone.

Marking medications and construction materials

Furthermore, this technology could be used to mark medications or construction materials such as adhesives or paints. Information about their quality could be stored directly in the medication or material itself, Grass explains. This means medical supervisory authorities could read test results from production quality control directly from the product. And in buildings, for example, workers doing renovations can find out which products from which manufacturers were used in the original structure.

At the moment the method is still relatively expensive. Translating a 3D-printing file like the one stored in the plastic rabbit's DNA costs around 2,000 Swiss francs, Grass says. A large sum of that goes towards synthesising the corresponding DNA molecules. However, the larger the batch size of objects, the lower the unit cost

Task 1

Find words/expressions meaning the following:
1. It is not so;
2. an action or system by which a result is achieved; a method;
3. to fix (an object) firmly and deeply in a surrounding mass;
4. by-product or incidental result of a larger project;
5. progress, achievement;
6. imitation, mimicking;
7. very small;
8. to keep;
9. in a fundamental or basic way;
10. to hide.

Task 2

Say whether the following is true, false or not mentioned.
1. Scientists found that nearly anything could be used as a huge storage device.
2. The information in such a thing is stored by means of DNA molecules.
3. The invention in question came as a by-product pf a discovery made a year ago.
4. Information can be stored in DNA far more densely than in hard drives or magnetic tape.
5. The creators of the two technologies mentioned in the article have recently had a wedding.
6. The method is called the DNA of things to point out that nearly every object contains its own DNA.
7. To prove that information can be stored for many generations the scientists printed a plastic rabbit and using its small part created a whole new one, repeating the process five times
8. The integrity of the data degraded a little each generation.
9. A possible use of the method is hiding data in ordinary things making it impossible to detect.
10. This technique is known as stenography.
11. The technology could also be used to make self-replicating robots
12. At present it is still unaffordable.

Task 3

Answer the following questions:

1. Does the sentence 'The way of storing this information is the same as for living things: in DNA molecules.' mean that every object has its own DNA? Why? Why not?
2. What made the new achievement possible?
3. Why was it called DNA of things?
4. How did the scientists prove it really worked?
5. How long could the information about the rabbit be used?
6. What makes DNA unique compared to other storage media?
7. How else can this technology be used?
8. What is steganography?
9. What makes the new technology so suitable for medicine?

23. NEW PARTICLE ACCELERATOR FITS ON A SILICON CHIP

As electrons flow through this channel etched in a silicon chip, laser light (shown in yellow and purple) accelerates the particles to high speeds. Credit: Neil Sapra

In a full-scale particle accelerator, electrons fly along a kilometers-long path as microwaves bombard them, boosting the particles to near light speed. Such a high-energy electron beam, produced at facilities such as California’s SLAC National Accelerator Laboratory, enables a variety of experiments, including capturing extremely detailed images and probing the structures of molecules. But particle accelerators are expensive, require scientists to travel from locations all over the world and cannot accommodate all the researchers who submit requests to book time. To make these devices more accessible, a team at Stanford University developed a laser-driven particle accelerator that fits on a tiny silicon chip – and that could eventually be scaled up to produce a beam with as much energy as SLAC’s.

“The idea of using lasers in accelerators goes all the way back to the year the laser was invented, 1960,” says Robert Byer, a Stanford researcher who has been working on this concept since 1974. Lasers produce electromagnetic waves with much shorter wavelengths than the microwaves used in a full-scale accelerator, which means they can accelerate electrons moving through a much smaller space. “The size of these devices is uncannily small,” Byer says. The electrons in the new accelerator, for example, travel along a channel that is about three one-thousandths of a millimeter wide – around half the width of a human red blood cell.

Although laser-driven devices can accelerate electrons in a much smaller space than full-scale accelerators, they also require much greater precision to line up the laser and the electrons in the right way, so the light waves push the particles in the correct direction with as much energy as possible. “You not only have to demonstrate the ability to couple the laser light to the electrons in these very small structures, but you have to generate the electrons and have them also be transmitted by the channel,” Byer explains. In 2013 two research groups, one at Stanford and other U.S. institutions and another in Germany, independently managed to accelerate electrons with lasers. But these proof-of-concept prototypes required separate devices to generate the electrons, and they would be difficult to manufacture in bulk using existing techniques.

A laser-driven accelerator engraved in silicon, however, would be easier to scale up, and multiple components could potentially fit on the same chip. Byer worked with several other researchers, including Stanford University electrical engineer Jelena Vuckovic, to produce such a tool. “What you have to design is the structure that will guide light in the right way, so light will always provide a kick in the right direction – so particles are always getting accelerated," Vuckovic says. To determine that structure, her student Neil Sapra used a computer to simulate how different patterns would interact with incoming electromagnetic waves. Once they had a design that accelerated the electrons as much as possible, and always did so in the right direction, the researchers etched this accelerator into a silicon wafer.

When the wafer is blasted with laser pulses from above, the laser light hits a grating called an "input coupler," which sends it moving along the length of the chip. Next, the light waves run into the computer-designed path that cuts across the width of the chip. As the light passes through, the pattern focuses the waves, so they impart energy to a beam of electrons shooting along the path. This energy pushes the particles forward faster. A description of the chip was published Thursday in Science.

"It's a quite promising paper," says Mark Palmer, director of the Accelerator Test Facility at Brookhaven National Laboratory, who was not involved in the new research. "I think they did a very nice job of showing how we can start to move forward with designing these structures and actually coming up with working devices, hopefully, in the not too distant future," he adds.

The Stanford researchers found their prototype could successfully boost the electrons' energy by 915 electron volts. Although that amount of energy is miniscule by everyday standards, the increase occurred as the electrons traveled only three one-hundredths of a millimeter – equivalent to them gaining about 30 million electron volts over the course of a meter. That change is not on the scale of what an accelerator like SLAC, which has many meters in which to power up its electrons by tens of billions of electron volts, can impart. The miniature accelerator can, however, scale up much more easily than its larger counterpart: because it is etched in a small silicon wafer, researchers can fit multiple accelerating paths into future designs without adding bulk.

"We showed a single stage of the accelerator," Vuckovic says. "It's very simple scaling going from this single stage to 1,000 stages on a single silicon wafer." She estimates that 1,000 stages could fit on a chip a couple of centimeters in length and imbue electrons with a million electron volts' worth of energy, allowing them to travel at about 94 percent of the speed of light. That achievement would be enough for researchers to carry out some experiments that currently require visits to accelerators like SLAC. Electrons with that amount of energy could also potentially enable medical applications, such as providing targeted radiation treatment for cancer patients without damaging healthy tissue. "We can basically make instruments where we can have very tightly focused electron beams, and can use this to selectively target tumors," Vuckovic says. She expects that her team could develop this scaled-up chip within a year, but that it may be about five years before the device can be used in practical applications, and even longer before it finds its way into medical treatments.

Palmer is more conservative with his estimates, guessing that applications may take 10 years to come to fruition. He is optimistic, however, about the impact accelerators on chips will have at that time. "At the end of the day, by [accelerating particles] in these small structures, you have devices that are readily adaptable to whatever environment you need to operate them in," he says, "as opposed to having a much larger particle accelerator that has to go into a very fixed sort of footprint."

Task 1

Find words/expressions meaning the following:
1. to make something possible, allow;
2. obtainable, available;
3. strangely or mysteriously;
4. in large quantities;
5. to wear away the surface of (a metal, glass, etc.) by chemical action;
6. a glass plate or a mirror with a large number of equidistant parallel lines or grooves on its surface;
7. to pass on, convey;
8. to permeate, saturate;
9. to occur or turn out as suspected or intended.

Task 2

Say whether the following is true, false or not mentioned.
1. The text implies that particle accelerators are scarce due to their price, which prevents scientists from using them any time they like.
2. It was only last year that scientists suggested using laser pulses to accelerate electrons.
3. As light wave length is very short you don't need large distances to accelerate electrons.
4. Though it is not the first time lasers have been used to accelerate electrons, never before have scientists been able to get an entire accelerator system built in a small space
5. Vuckovic managed to find the right light guiding structure experimenting with different materials.
6. Though laser accelerators have the advantage of being small, extra care should be taken in aligning the laser and electrons.

7. This discovery can be compared to the work engineers once did to compress the power from room-sized mainframes into desktop PCs.
8. The power of large accelerators like SLAC pales in comparison with that of laser accelerators.
9. A two centimeter chip could accelerate electrons almost to the speed of light.
10. The Stanford team carved a nanoscale channel out of silicon – less than the width of a human hair – sealed it in a vacuum, and then propelled electrons through it using pulses of infrared light.
11. The team have different opinions about the time it will take to complete the project.
12. Because infrared cannot travel through copper – the material used in most larger microwave accelerators – the Stanford team had to recreate an accelerator with silicon.

Task 3

Answer the following questions:
1. How are ordinary particle accelerators applied?
2. What is their main drawback?
3. What makes laser-driven devices different?
4. How do they work?
5. What disadvantage did the first laser-driven devices have?
6. How was the problem solved?
7. Can we say that they produce as much energy as large-scale accelerators? Why? Why not?
8. How can their energy be increased?
9. Why have the scientists so many expectations of the devices?
10. How do they differ about the time needed to apply the device for practical purposes?

SOURCES OF REFERENCE

economist.com
dailymail.co.uk
discover.com
phys.org
sciencedaily.com
scientificamerican.com

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