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DEFTECH Update

November 2017

Dear Reader,

This document summarizes emerging technology signals related by Strategic Business Insights' (SBI) Scan and Explorer services that the Technology Foresight Research Program from armasuisse Science + Technology subscribes to.

For each trend, we try to anticipate what could be the implications for the armed forces. Each trend is also related to the original signal of change elaborated by SBI that the interested reader finds at the end of this document.

The intent is to stimulate strategic technology forward thinking in a form that is pleasant and quickly readable.

It is the last one of the 2017 series and we will provide something similar, but different (!) in 2018.

We hope you enjoy the journey!

Best regards,

Dr. Quentin Ladetto
Research Director – Technology Foresight

P.S. For any comment, suggestion or discussion: quentin.ladetto@armasuisse.ch

Image source: The Telegraph website

Flying Cars: This Time for Real?: Although "flying cars"—vertical-takeoff-and-landing (VTOL) aircraft—are still years away, multiple companies are now looking into the technical feasibility of the concept. For example, Uber Technologies recently announced plans to demonstrate flying cars by 2020.

Implication for Defense and Security*: Flying cars, that combine the capabilities of road-based vehicles and helicopters, could enable militaries to rapidly evacuate personnel or transport supplies in areas that are inaccessible to helicopters or road-based vehicles alone. Ordinary soldiers may be able to operate flying cars without pilot training.*

Timing of Implication: *now/5 years/10 years/****15 years***

Image source: Azo Materials website

Stronger Materials: Scientists are constantly striving to develop materials that are stronger and lighter than are conventional materials to act as enablers for applications in areas such as transportation and infrastructure. Computer modeling is playing a significant role in the design of strong materials.

Implication for Defense and Security*: Computational materials engineering could accelerate the discovery of high-strength materials for military and defence applications such as advanced armour and vehicle lightweighting to increase fuel efficiency.*

Timing of Implication: ***now/5 years****/10 years/15 years*

Image source: MIT website

Blockchain Security Solutions: Blockchains, the technology underlying cryptocurrencies such as Bitcoin, offer a fundamentally different approach to cybersecurity. The US Naval Innovation Advisory Council recently announced plans to test the use of blockchain technology to share data securely between its additive-manufacturing sites.

Implication for Defense and Security*: Blockchain technology could provide defence and security organizations with a secure and tamper resistant means of sharing and tracking many kinds of data online, thereby protecting them against cyberthreats. Opportunities also exist for defence and security organisations to use blockchain technology to streamline digital workflows.*

Timing of Implication: *now/5 years/**10 years**/15 years*

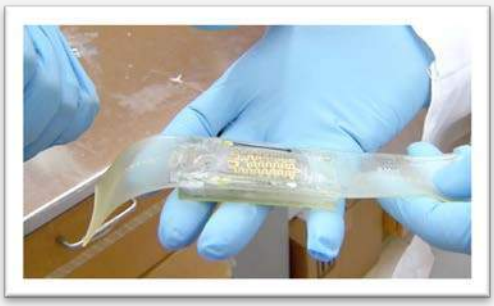

Image source: Intersog website

Nanoelectronic Smart Bandages: Researchers at Swansea University's Institute of Life Science have developed smart bandages—wound dressings containing nanoelectronic sensors that capture and communicate real-time data about the healing progress of a patient's injury as well as their activity and location.

Implication for Defense and Security*: Smart bandages could reduce the number patient checkups and help clinicians to provide tailored patient care, enabling soldiers to resume combat duties more quickly after injury. Militaries could reduce health-care expenditures. Additionally, smart bandages may improve treatment of minor injuries in the field.*

Timing of Implication: *now/5 years/**10 years/15 years***

Image source: Inside Financial Markets website

New Sources of Raw Materials: Concerns about the supply security of certain raw materials are driving efforts to access new sources of those materials. For example, government and private organizations are establishing programs to explore the potential of space-based mining.

Implication for Defense and Security*: New sources of raw materials could ensure the stable supply of materials that find use in military-transport systems, weapons, sensors, and communication systems. Countries with strategic raw materials may use their reserves to gain advantage. A lack of supply of strategic materials could leave defense organizations vulnerable to disruption.*

Timing of Implication: *now/5 years/10 years/****15 years***

Image source: The Temp Connection website

Hacking: Now Accessible and Pervasive: Complex cyberattack methods are becoming more accessible to, and lucrative for, malicious users. The number and severity of exploits are hinting at the arrival of an era in which cyberattacks can reach nearly any industry or device and cause significant damage.

Implication for Defense and Security*: The future impacts of cyberattacks are becoming more uncertain. Defense and security organizations could benefit from implementing agile methodologies to planning and cyber security investment. But, defense and security organizations are attractive targets to cyberattackers, and the rate and severity of cyber attacks will likely increase.*

Timing of Implication: ***now/5 years****/10 years/15 years*

Image source: Dezeen website

A Wider Range of 3D-Printing Materials: A considerable amount of research is under way to develop new techniques and new materials (such as cellulose and glass) for 3D printing, and advances in this area could open up new applications for 3D-printing technology.

Implication for Defense and Security*: Opportunities could exist for defence and security organizations to use 3D-printing technology to quickly fabricate custom components for weapons, medical equipment, or military vehicles and equipment in the field.*

Timing of Implication: now/5 years/10 years*/15 years*

Image source: The Engineer website

Aquatic Megaprojects: Several proposed aquatic megaprojects have the potential to connect countries and change global logistics. Proposed projects include a canal in Iran that will run hundreds of miles from the Caspian Sea to the Persian Gulf and a floating island on a North Sea sandbank.

Implication for Defense and Security*: Aquatic megaprojects could represent a threat to national security by facilitating illegal immigration and importation of contraband, or the rapid deployment of militaries to foreign grounds. Conversely, militaries could gain strategic advantage through the development of floating military bases in regions where land is not available.*

Timing of Implication: *now/5 years/****10 years/15 years***

Image source: Tech Crunch website

Robo Delivery: In the future, road vehicles may work together with drones and robots to deliver packages to people. Companies are in conceptual or experimental phases of investigating robo delivery.

Implication for Defense and Security*: Delivery robots could save lives by replacing soldiers that transport supplies, equipment, or aid-relief in the field. Delivery robots could also perform some of the functions of conventional military robots such as surveillance or search and rescue.*

Timing of Implication: *now/5 years/**10 years/15 years***

Image source: Canvas Community website

Sensing with Ultrawideband Radar: Ultrawideband radar (UBR) has potential to sense through walls and detect subtle movements, including a person's vital signs. The technology is not new but is seeing some progress toward increased commercialization.

Implication for Defense and Security*: Falling UBR costs could expand the use of the technology by defense and security organizations. Potential applications include wireless and remote health monitoring, though-wall surveillance, mobile-security systems, and collision-avoidance systems for vehicles and light aircraft.*

Timing of Implication: *now/**5 years/10 years**/15 years*

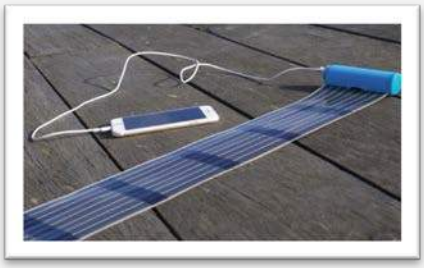

Image source: Best Portable Solar Generators website

Solar-Power Enablers: Solar power is an increasingly competitive energy that is seeing record use in many countries. New technologies are enabling innovative ways to use and store solar power and to reduce the cost of operating solar systems.

Implication for Defense and Security*: Solar panels are a low-cost emergency-power solution for field-based security and defense personnel without access to conventional recharging infrastructure. Opportunities exist to recharge portable-electronic devices and electric-vehicle batteries, or to power remote sensors and cameras. Militaries could substitute noisy diesel generators with solar panels that operate silently, and reduce fuel-transportation costs.*

Timing of Implication: ***now****/5 years/10 years/15 years*

Image source: Wireless Communication Systems website

Ultrareliable Low-Latency Communications: Ultrareliable low-latency communications (URLLC), with data transfer speeds in the order of one millisecond, could enable communications between devices with an "imperceptible time lag."

Implication for Defense and Security*: Opportunities exist for defense and security organizations to use URLLC for mission-critical applications such as remote communications, anti-collision systems, vehicle-to-infrastructure communications, or cloud-based guidance for drones.*

Timing of Implication: *now/****5 years/10 years****/15 years*

September 2017

P1116

Flying Cars: This Time for Real?

By Martin Schwirn (Send us feedback.)

Multiple companies are considering the development of flying cars.

Abstracts in this Pattern:

SC-2017-08-02-021 on Uber Technologies

SC-2017-08-02-025 on Airbus and Italdesign

The flying-cars concept has alternatively seen use in depictions of utopia, as a target of technological derision, and as a representation of unachievable expectations of progress. Multiple companies are now looking into the technical feasibility of the concept.

Uber Technologies (San Francisco, California) recently announced plans to demonstrate "flying cars"—vertical-takeoff-and-landing (VTOL) aircraft—in Dallas-Fort Worth, Texas, and in Dubai, United Arab Emirates, by 2020. The company plans to run pilot programs after the demonstrations and offer app-based flight-hailing services by 2030. However, Uber foresees technological and regulatory hurdles, and recent upheavals within the company could make developing the concept more difficult. Uber partnered with several aircraft manufacturers to develop the VTOL aircraft, which will initially require human pilots but eventually, Uber hopes, operate autonomously.

In 2016, Airbus Group (Blagnac, France) launched multiple projects in an effort to commercialize autonomous commuter aircraft within a decade—a goal that aims to address increasing traffic congestion in the world's cities (see SC-2016-11-02-080). More recently, a collaboration between Airbus and design house Italdesign Giugiaro (Volkswagen Group; Wolfsburg, Germany) produced Pop.Up—a vehicle concept that combines elements of self-driving cars and VTOL aircraft. Pop.Up's "removable passenger cell rides on the ground atop an electric vehicle chassis and decouples from that chassis to fly through the air below the whirring rotors of a self-piloted multicopter."

The flying-cars concept will likely remain as speculative—and perhaps as elusive—as it has been in past decades. But media interest in Uber Technologies' forays into autonomous cars and related activities has brought attention to the concept again, and Airbus's interest in the concept could give it some credibility that interest from other companies might be unable to provide.

Signals of Change related to the topic:

SoC915 — …Urban Mobility
SoC912 — Considering Driverless Infrastructures
SoC791 — Automotive Business Models…

Patterns related to the topic:

P1078 — Personalized Mobility Services
P1012 — Traffic-Data Services
P0910 — …Smart Driving

September 2017

SoC968

Stronger Materials

By Marianne Monteforte (Send us feedback.)

Conventional materials such as concrete, steel, metal, glass, brick, and wood still dominate many industries. Materials scientists are constantly striving to develop materials that are stronger and lighter than are conventional materials to act as enablers for applications in areas such as transportation and infrastructure. Automotive and aerospace manufacturers are the main players that have already integrated a variety of strong (and light) materials into their commercial products. These players aim to use many of these materials to replace metals, which are heavy and therefore lower vehicles' fuel efficiencies. The construction industry is large and could greatly benefit from innovations in materials technology. For example, innovative high-strength materials could see use to create buildings that are more resilient than are buildings that use conventional materials (see P1053 — Resilient Infrastructure Materials).

The geometric construction of and ordering of atoms in materials can provide materials with strength.

Many materials have some extraordinary high strength and already see use in some commercial applications. For example, advanced composites have emerged as a commercially viable competitor to pure metals in transportation applications. Carbon-fiber-reinforced composites already have a proven track record for their use in many advanced-composite applications, including aerospace and automobile components. Researchers at the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts) recently discovered a link between the random order of carbon atoms in a baked resin and the resin's density and strength. This discovery enabled the researchers to identify a baking temperature for the carbon fibers that maximizes the random orientation of the carbon atoms, resulting in a light material with very high strength.

Researchers at Singapore's Agency for Science, Technology and Research (Singapore, Singapore) used nanoparticles to enhance the strength of Inconel 625—a 3D-printable superalloy with superior mechanical characteristics. The researchers developed the high-strength superalloy composite by reinforcing Inconel 625 with titanium diboride nanoparticles. Because of its high corrosion-fatigue strength, high tensile strength, and resistance to chloride-ion stress-corrosion cracking, Inconel 625 already finds use in marine applications. The researchers' tests revealed that adding nanoparticle reinforcements to the superalloy provided the material with additional strength, microhardness, and abrasive resistance.

Materials that are available in nature can also aid in creating strong materials and find use in architectural applications. SoC704 — Incredible Materials discusses Zeo's (Mullumbimby, Australia) development of Zeoform—a strong, versatile new building material that contains cellulose and water. Zeoform is a hardwood-like material that can be sprayable and moldable and could serve as an environmentally friendly alternative to many structural plastics and resins. And SoC944 — Exploring Biobased Materials discusses the work of researchers from Newcastle University and Northumbria University (both Newcastle upon Tyne, England) who are using genetically modified *Escherichia coli* bacteria to produce *biocement*—a material consisting of calcium carbonate formed by bacteria in soil—in response to pressure. According to the researchers, once the genetically modified bacteria

are in the soil, they will respond to pressure from a structure by producing biocement, thereby strengthening the soil to support the structure. The researchers' approach could find use in a variety of architectural applications; however, concerns about introducing genetically modified bacteria into native soil may create barriers to the commercialization of the approach.

Some researchers are designing biomimetic materials that mimic the nanoscale properties of naturally strong materials. For example, researchers from MIT and other institutes drew inspiration from the complex internal structure of bones and developed a new type of steel with increased resistance to failure. The researchers "fabricated steel with thin, alternating nanoscale layers of different crystal structures, some of which were just unstable enough to morph a bit under stress. That complicated microstructure prevented cracks from spreading in a straight line, slowing their take-over and preventing the material from collapsing" ("Bone-inspired steel cracks less under pressure," *Science News*, 4 April 2017; online). Although this material is at the very early stages of development and requires substantial additional testing before it can see commercial use, its underlying nanoscale-layering principle is applicable to other mixed-composition metals as well. The principle may eventually enable the construction of more resilient bridges and buildings and make possible the use of new shapes and forms in architectural applications. SoC870 — The Art of Nanoscale Manufacturing's Science discusses a study of *diatoms*—minute unicellular marine algae—by researchers from the California Institute of Technology (Pasadena, California) and the Norwegian University of Science and Technology (Trondheim, Norway). The study revealed that diatoms' protective biosilica shells have remarkable physical strength: "The honeycomb sandwich plate cross-section of the silica shell allows the diatom to maintain high strength while keeping weight low. Combining this architecture with a silica-organic composite as the constituent material gives the diatom shell the greatest strength-to-weight ratio of all previously reported natural biological materials" ("Tiny Diatoms Boast Enormous Strength," California Institute of Technology, 8 February 2016; online). The researchers plan to use diatom-inspired design principles to create high-strength artificial structures.

The geometric construction and ordering of atoms of materials can provide materials with strength, and computer modeling can play a significant role in the design of strong materials. For example, MIT researchers used atomistic computer modeling in their efforts to fuse and compress two-dimensional graphene flakes into strong, lightweight three-dimensional structures (see P1079 — Computer Modeling as an Enabler). The researchers optimized the geometric arrangement of the graphene-based material to create a very strong structure. Using a 3D printer, the researchers printed large versions of these microscopic structures for mechanical testing.

The commercial developments and research this SoC discusses indicate that materials science is far from reaching its limits, and the creation of increasingly strong lightweight materials is possible. Such materials do currently face some commercial constraints. For instance, current building regulations can hinder the use of innovative materials, and the flammability of many adhesives and composite materials could also present difficulties. Nevertheless, keeping a keen eye on developments in materials science, including the creation of innovative materials and improvements to existing materials, could prove essential for companies in many industries.

SoC968

Signals of Change related to the topic:
SoC944 — Exploring Biobased Materials
SoC870 — …Nanoscale Manufacturing's Science
SoC704 — Incredible Materials

Patterns related to the topic:
P1079 — Computer Modeling as an Enabler
P1053 — Resilient Infrastructure Materials
P0996 — Biological Material in Architecture

STRATEGIC BUSINESS INSIGHTS

EXPLORER

Viewpoints

September 2017

Nanoelectronics

By Alastair Cunningham (SBI Technology Analyst: Guy Garrud, ggarrud@sbi-i.com)
Cunningham is an independent consultant specializing in nanomaterials and electronics.

Nanoelectronic Smart Bandages

Why is this topic significant? Nanoelectronics already plays a pivotal role within the integrated-circuit industry. However, recent research demonstrates how the technology can support a wide range of other applications, such as smart bandages for the health-care sector.

Description

In April 2017, researchers at Swansea University's Institute of Life Science announced the results of their research into smart bandages—a wound dressing containing nanoelectronic sensors that can detect an injury's healing progress and communicate related information back to doctors. The bandage would essentially link the wound directly into a 5G infrastructure in real time. Through a smartphone, doctors could access this information and also access other patient data such as location or activity.

A linear log of healing, in addition to these other data, enables clinicians to provide tailored medical advice for the patient. The multidisciplinary project involves experts in nanotechnology who fabricate the sensors and a team specializing in 3D printing that incorporates the devices into bandages. The team announced in May 2017 that it hopes to start patient-based trials of the product within 12 months, stating in a Swansea University press release that the trials would take place in southwest Wales. This research forms part of a wider, £1.3 billion scheme to create a 5G test hub for digital innovation in and around the Swansea area.

Implications

If successful, the Swansea University innovation and others like it could revolutionize global health care and positively affect patient outcomes. A real-time analysis of wound healing would enable medical professionals to deliver the very best in health care while simultaneously reducing the burden on health services.

The multidisciplinary aspect of the project—which involves nanotechnology researchers, biochemists, 3D-printing experts, health-care professionals, 5G-networking technicians, and leaders in business innovation—is an important feature of this development. Increasingly, such a convergent approach will be necessary if researchers are to deliver truly innovative products and

applications. Indeed, the 3D-printing techniques that the team employs are likely to prove crucial to any long-term commercial success that may result from this work—as will cost reduction to make the technology affordable for health services that will ultimately form the market for these products.

Impacts/Disruptions

The term *precision medicine* encapsulates far more than smart bandages and wound healing. The use of genomic analyses to determine, for example, which drugs would prove most effective for a particular patient is likely to have an enormous impact on patient care. That nanoelectronic devices could contribute to such patient stratification is perhaps unsurprising given the ubiquity of the technology and the wide range of other applications in which it is finding use. The market for health nanoelectronics, driven by aging populations and enabled by technological progress, is likely to grow and will play an increasingly important role in the provision of health care in the coming years.

Scale of Impact	Low		Medium	**High**
Time of Impact	**Now**	**5 Years**	10 Years	15 Years

Opportunities in the following industry areas:
Sensors, health care, network communications, 3D printing

Relevant to the following Explorer Technology Areas:
• Nanoelectronics • Nanomaterials • Nanobiotechnology • RFID Technologies • 3D Printing • User Interfaces

STRATEGIC BUSINESS INSIGHTS

EXPLORER

Viewpoints

September 2017

Nanoelectronics

By Alastair Cunningham (SBI Technology Analyst: Guy Garrud, ggarrud@sbi-i.com)
Cunningham is an independent consultant specializing in nanomaterials and electronics.

IBM Nanosheet

Why is this topic significant? Advances in semiconductor technology will be necessary if the integrated-circuit industry is to support the intense computing requirements of the future. Recent IBM research represents a significant step toward commercialization at the 5-nanometer node.

Description

In June 2017, an IBM-led collaboration, which also includes GlobalFoundries and Samsung, released the results of its research into silicon nanosheet transistors that could enable the fabrication of chips at the 5-nanometer node. IBM claims that this development represents "the first in the industry to demonstrate the feasibility to design and fabricate stacked nanosheet devices with electrical properties superior to FinFET [fin field-effect transistor] architecture." The collaborators also state that their new process could yield fingernail-size chips that contain 30 billion transistors—considerably more than the 20 billion transistors on the 7-nanometer-node test chip IBM developed in 2015.

IBM invested more than a decade of research into nanosheet semiconductor technology before achieving its recent success at the 5-nanometer node. The ultimate breakthrough came as a result of a fundamental shift in chip architecture. By transitioning from the vertical FinFET structures that find use in today's electronic devices to horizontal layers of silicon nanosheets, IBM demonstrated the opening of what it terms "a fourth 'gate' on the transistor that enabled electrical signals to pass through and between other transistors on a chip."

The collaboration's change in architecture and the concomitant increase in chip density yield significant advantages. A 40% enhancement of performance at fixed power—or 75% power savings at identical levels of performance—is what 5-nanometer technology achieves, as against the state-of-the-art 10-nanometer technology currently on the market.

Implications

First and foremost, IBM's recent research provides evidence that 5-nanometer silicon chips are possible, that the chips exhibit significant performance advantages over current state-of-the-art technology, and that their commercialization in the midterm future is a distinct possibility. The performance

advantages afforded by integrated circuits based on 5-nanometer chips will be significant. For example, smartphone batteries could potentially last two to three times longer than they do at present because of more energy-efficient processing.

IBM (alongside its partners) is in a perfect position to capitalize on its industry-leading status. The company is, in its own words, "aggressively pursuing" novel architectures and materials that will enable it to move ahead of the curve in terms of introducing (and commercializing) industry-leading technologies. By planning several technology nodes down the line, IBM is attempting to ensure its mid to long-term position as a market leader within the integrated-circuit industry.

Impacts/Disruptions

This development represents a substantial step forward for the entire semiconductor industry, and the technology is likely to become an industry standard once the 7-nanometer node and FinFET technology runs its course. Moreover, the computing power enabled by these integrated circuits will facilitate a wide range of data-intensive applications—from cognitive and cloud computing to virtual-reality systems and next-generation mobile devices. However, as with the majority of other novel semiconductor technologies, the lag between discovery and commercialization is likely to be about ten years.

Scale of Impact	Low	Medium	**High**	
Time of Impact	Now	5 Years	**10 Years**	15 Years

Opportunities in the following industry areas:
Semiconductor, consumer electronics, cloud computing

Relevant to the following Explorer Technology Areas:
• Nanoelectronics • Nanomaterials • MEMS/Micromachining • Pervasive Computing

September 2017

P1115

New Sources of Raw Materials

By Cassandra Harris (Send us feedback.)

Concerns about the supply security of certain raw materials are driving efforts to access new sources of those materials.

Abstracts in this Pattern:

SC-2017-08-02-018 on deep sea
SC-2017-08-02-084 on asteroids
SC-2017-08-02-079 on microbes

Many emerging renewable-energy and sustainable technologies require materials that are at risk of supply disruption. For example, tellurium is a rare-earth metal that finds use in commercial cadmium telluride solar cells, but it can be difficult for manufacturers to obtain. In April 2017, however, researchers from the National Oceanography Centre (Natural Environment Research Council; Swindon, England) discovered that the rock coating an underwater mountain 1 kilometer below the surface of the Atlantic Ocean contains 50,000 times more tellurium than any known land-based deposits. According to expedition leader Bram Murton's calculations, the mountain could contain more than 2,500 metric tons of tellurium. Outer space may also provide opportunities for mining crucial raw materials. For example, in May 2017, the chief commander of the Chinese Lunar Exploration Program (China National Space Administration; Beijing, China) announced plans to mine near-Earth asteroids for precious metals. It hopes to launch its first spacecraft for asteroid exploration by 2020 and eventually to develop robotic technology capable of excavating asteroids and transporting mineral ores from asteroids to Earth. Mining in the deep sea and on asteroids presents significant cost and engineering challenges, but conducting mining operations in these environments could aid in ensuring a secure supply of various raw materials.

Microbes may represent another new source of raw materials. Researchers are finding ways to harness the metabolic processes of microbes to produce commercially useful compounds on a large scale. For example, Massachusetts Institute of Technology (Cambridge, Massachusetts) spin-out Manus Bio (Cambridge, Massachusetts) claims that it has created a low-cost fermentation process for engineering microbes that produce large quantities of rare and expensive compounds for use in products such as pharmaceuticals, flavors, and pesticides. The company claims that, on average, its fermentation process produces compounds at one-tenth the cost of processes that extract compounds from plants. Such microbial-engineering techniques may enable the production of a variety of materials that exist on Earth in concentrations that are too low to extract economically with present-day technologies.

Signals of Change related to the topic:

SoC944 — Exploring Biobased Materials
SoC778 — Shifts in Materials' Production…
SoC643 — Waste as…Feedstock

Patterns related to the topic:

P1065 — Wasted Opportunities
P1053 — Resilient Infrastructure Materials
P0996 — Biological Material in Architecture

STRATEGIC BUSINESS INSIGHTS

scan™

September 2017

SoC963

Hacking: Now Accessible and Pervasive

By Sean R. Barulich (Send us feedback.)

Complex cyberattack methods are becoming more accessible to and lucrative for malicious users. The simplicity and effectiveness of denial-of-service (DDoS) attacks and malware such as ransomware and spyware have helped open up cyberweapons for pervasive use. New exploits are hinting at the arrival of an era in which cyberattacks can reach nearly any industry or device and cause significant damage.

A recent study by researchers from Trend Micro (Tokyo, Japan) and the Polytechnic University of Milan (Milan, Italy) revealed that many connected industrial robots in use in manufacturing facilities are insufficiently secure and can leave companies vulnerable to cyberattacks. The researchers used search services that conduct internet scans to find connected devices. These searches found more than 83,000 connected industrial robots from five prominent vendors, including ABB (Zurich, Switzerland) and Kawasaki Heavy Industries (Tokyo, Japan). The study revealed that "of the more than 83,000 exposed industrial robots, 59 had known vulnerabilities and more than 5,100 had no authentication" ("Industrial robots are security weak link," *Computerworld*, 9 May 2017; online). Such weak security could enable hackers to gain access to a robot's control system and alter its actions, which could result in the robot's damaging equipment, making unsafe products, and even injuring human workers. All internet-connected devices—from Internet of Things (IoT) consumer devices to connected industrial machines—are at some risk of experiencing cyberattacks. As an increasing number of objects and devices gain connectivity, new hacking methods and types of cyberattacks will likely emerge and see use.

In combination, the increasing number of connected devices and the simplicity of some exploits are creating an environment in which products face constant exposure to growing security risks.

Some new cyberattacks focus on exploiting large quantities of consumer devices. In January 2017, criminals exploited a vulnerability in Signaling System No. 7 (SS7)—a protocol that coordinates how cell phones exchange text messages and voice calls—to circumvent banks' multifactor authentication and gain access to and drain victims' bank accounts. The cyberattack consisted of two parts: "First, the hackers used phishing tactics and malware to access account numbers, passwords and balances. Then, they were able to use the bug in the SS7 network to redirect authorisation text messages to separate mobile devices before logging in" ("SS7 hack: Cyber-thieves exploit worldwide mobile network flaw to 'drain' bank accounts," *International Business Times*, 4 May 2017; online). Exploiting SS7 could also enable attackers to listen in on phone calls and track victims' locations. This incident prompted concerns that the protocol that operates 4G and could operate the 5G networks of the future may be similarly insecure.

In combination, the increasing number of connected devices and the simplicity of some exploits are creating an environment in which products face constant exposure to growing security risks. Wikileaks (https://wikileaks.org) has released multiple sets of documents that discuss exploits, hacking and surveillance tools, and malware reportedly in use by the US Central Intelligence Agency (CIA; Langley, Virginia) to attack software and consumer devices around the world. Some of these documents describe

hardware and software exploits capable of giving attackers complete access to and control over devices such as routers, smartphones, and smart televisions.

Ransomware—malware that enables attackers to use standard encryption to lock down a victim's data until the victim pays (typically in a cryptocurrency) the attacker to decrypt them—is seeing increasing use. For example, the WannaCry self-replicating ransomware infected tens of thousands of computers across at least 74 countries in May 2017, issuing ransom demands in more than 24 languages. WannaCry made use of the EternalBlue exploit, which was likely developed by the US National Security Agency (NSA; Fort Meade, Maryland) and can see use to gain control of computers using various versions of Microsoft's (Redmond, Washington) Windows operating system. (EternalBlue saw use again in June 2017 to support the NotPetya cyberattack.) WannaCry demonstrated that ransomware is not only easy to deploy but also capable of spreading virally. The increase in ransomware-attack frequency and sophistication is likely a result of a number of key factors. First, ransomware provides attackers with lucrative opportunities to exploit the poor data-backup practices of many victims. Second, cryptocurrencies have supported ransomware attacks by giving attackers a way to launder and transfer money anonymously. Third, the use of mainstream encryption makes ransomware simple by design, and using cyberweapons and exploits to launch ransomware attacks has become relatively easy for attackers.

Spyware—malware that enables the user to gain access to and gather information from someone's computing device surreptitiously—is seeing increasing use by people who lack cybersecurity or technical backgrounds. Hackers recently leaked a sizable group of files from device-monitoring-software developers Retina-X Studios (Jacksonville, Florida) and FlexiSpy (Vervata Co.; London, England), revealing that roughly 130,000 people have had accounts with the companies. A user who installs spyware from these companies on a target's cell phone may be able to intercept phone calls; monitor chats in various applications; see text messages, internet-browser history, and GPS location data; and switch on the phone's microphone. This type of consumer spyware enables people to stalk victims, and it has seen use in multiple cases of domestic abuse and civilian espionage. Conceivably, even someone with minimal computer skill could use such spyware with a keylogger to obtain passwords for important accounts. The accessibility and efficacy of consumer spyware significantly increases risk in both personal and mobile computing.

The proliferation of cyberweapons and espionage tools has amplified the effectiveness and ease of use of various types of malware by increasing the number of vectors the malware can use to infect systems. Online marketplaces that provide malware support a culture of *black-hat hacking*—hacking for personal or malicious reasons—by people who lack the technical experience that hackers have typically possessed. Because of this underground malware economy, people will likely develop new easy-to-use hacking tools and discover *zero-day exploits*—software vulnerabilities unknown by the software authors—with minimal regard to the consequences. The threat to cybersecurity will likely increase when people outside the professional cybersecurity field who possess little technical knowledge obtain simple-to-deploy high-grade cyberweapons.

SoC963

Signals of Change related to the topic:
SoC946 — Diffusion of Hacking…
SoC902 — Unusual Hacking, Atypical Spying
SoC875 — Hacking to Manipulate

Patterns related to the topic:
P1081 — Cyber(in)security
P1036 — Hacking's Reach Expands
P1021 — Proliferating DDoS Attacks

September 2017

P1108

A Wider Range of 3D-Printing Materials

By Guy Garrud (Send us feedback.)

The range of materials finding use in the 3D printing of objects is widening, establishing new 3D-printing applications.

Abstracts in this Pattern:

SC-2017-08-02-100 on metal keys
SC-2017-08-02-027 on glass
SC-2017-08-02-065 on cellulose
SC-2017-08-02-091 on dusts
SC-2017-08-02-092 on chain-mail-like material

A considerable amount of research is under way to develop new techniques and new materials for 3D printing, and advances in this area could open up new applications for 3D-printing technology. For example, UrbanAlps (Zurich, Switzerland) has developed a 3D-printed mechanical metal key with a shape that conceals the key's teeth from view. This design prevents the clandestine copying of the key's tooth pattern. Using more traditional machine-tooling techniques rather than 3D printing to manufacture the metal keys would be extremely difficult.

Glass is also finding use in 3D-printing approaches. Researchers from the Karlsruhe Institute of Technology (Karlsruhe, Germany) developed a process in which they place a high concentration of glass nanoparticles into a liquid that hardens on exposure to ultraviolet (UV) light. The liquid then "sits in a container and is exposed, slice by slice, to UV light that has been programmed to create different shapes at each layer. The regions that are exposed become solid. Heating the structure in a high-temperature furnace…burns away the leftover liquid and fuses the glass nanoparticles together."

Glass is attractive to 3D-printing researchers because of its chemical and thermal stability and its optical properties, but other materials are of interest because of their sheer abundance or availability. Researchers at the Massachusetts Institute of Technology (Cambridge, Massachusetts) have developed a method for 3D printing with cellulose. Because cellulose is an organic polymer present in most plant matter, it is inexpensive, biodegradable, and renewable. And scientists at Northwestern University's (Evanston, Illinois) Tissue Engineering and Additive Manufacturing laboratory have explored using facsimiles of Martian and lunar dust in 3D printing. The researchers envision their technique's seeing use to fabricate shelters and other objects from the dusts available on future space missions. NASA (Washington, DC) is actively exploring potential uses of 3D printing. Two 3D printers are now aboard the International Space Station, and NASA engineers are using metal to 3D print a chain-mail-like material. The material's interlocking tiles feature a shiny outer surface that reflects radiation and a heat-absorbing inner surface that can insulate spacecraft and space suits.

Signals of Change related to the topic:

SoC944 — Exploring Biobased Materials
SoC922 — Opportunities in Space
SoC900 — Leveraging the Maker Movement

Patterns related to the topic:

P1054 — On-Demand Manufacturing…
P1050 — 3D Printing in Medical Applications
P1003 — Altering Adhesion

August 2017

P1103

Aquatic Megaprojects

By Marianne Monteforte (Send us feedback.)

If successful, several proposed aquatic megaprojects have the potential to connect countries and change global logistics.

Abstracts in this Pattern:

SC-2017-07-05-027 on canals
SC-2017-07-05-032 on tunnel
SC-2017-07-05-013 on island

New aquatic-infrastructure projects could dramatically improve trade and transportation and are therefore relevant to most industries. For example, Nicaragua's Supreme Court has granted permission for the construction of a transcontinental canal that will compete with the Panama Canal (see SC-2013-08-07-029). This canal is one of several proposed canals that will create new routes for cargo ships. Other proposed projects include a canal in Thailand that will link the Indian Ocean and the South China Sea and a canal in Iran that will run hundreds of miles from the Caspian Sea to the Persian Gulf. These proposed megaprojects could significantly alter the economies of their host countries.

Other major aquatic-infrastructure projects are also getting the go-ahead as developers become more daring in attempts to cut travel distances, times, and costs. For example, Norway plans to build the Stad Ship Tunnel—the world's first tunnel for ships. Constructing the tunnel, which will be more than a mile long and 118 feet wide, will require burrowing through a rocky peninsula. Construction should commence in 2018 or 2019 and cost a minimum of 2.7 billion kroner ($314 million). The tunnel will accommodate large cruise and freight ships and should open in 2023. Such transportation megaprojects could drive advances in design and engineering, construction capabilities, and the use of novel materials.

In recent years, a variety of concepts for artificial islands—including artificial islands that serve as industrial hubs and even floating cities—have also emerged. TenneT (Arnhem, Netherlands) and Energinet (Fredericia, Denmark) have formed a partnership to investigate building a large island on a North Sea sandbank. The island's purpose is to "act as a staging post for turbine operations and maintenance crews, as well as to provide a central connection for planned far-shore wind farms and host direct current lines acting as interconnectors between Denmark, Germany, Holland, Norway and the U.K." If this island-energy-hub megaproject is successful, interest in similar megaprojects could increase significantly.

Signals of Change related to the topic:

SoC914 — …Aquatic…Infrastructures
SoC907 — Public Transportation in Transition
SoC901 — Logistics and Infrastructure

Patterns related to the topic:

P0981 — Automating Transportation
P0836 — Transforming Cargo Transportation
P0552 — Epic Transportation Projects

STRATEGIC BUSINESS INSIGHTS

EXPLORER

Viewpoints

August 2017

Connected Cars

By Katerie Whitman (kwhitman@sbi-i.com)

Robo Delivery

Why is this topic significant? In the future, road vehicles may work together with drones and robots to deliver packages to people—provided that stakeholders can address many challenges.

Description

Online retailer Amazon.com's delivery drones are perhaps the most well-publicized example of a concept in which robots—instead of humans—deliver packages to individual recipients. In demonstrations, a person first orders an eligible (lightweight) item for delivery using the Amazon app. At a nearby fulfillment center, robot-assisted workers pick the item, pack it, and then place it on a conveyor that loads the package on a waiting drone. The drone carries the package to a landing site at the customer's home and drops it off and then returns to collect another package.

Several other companies are in conceptual or experimental phases of investigating robo delivery. Daimler has shown renderings of a delivery van that acts as an automated mother ship for delivery drones. The van, carrying cargo alongside rows of drones that are racked in battery-charging mounts, first drives to a location near its destination, and then one or more drones depart with packages for delivery. United Parcel Service is one of many shipping companies that have also been experimenting with the drone-carrying-van concept. Many companies are also testing wheeled delivery robots of various kinds, including robots that can travel on sidewalks. In some visions, the robots integrate with specialty vehicles, some of which might one day be driverless.

Thus far, actual deployments of robo-delivery systems have been rare. Online retailer JD has apparently been delivering items to actual customers using high-capacity drones in select locations in China. Wheeled delivery robots are present in the hospitality and medical industries, where they deliver small items to hotel rooms or to patients' rooms.

Implications

Companies that wish to offer robo-delivery services have many challenges to overcome. Drone technology is not yet advanced enough to allow for drone-based deliveries to become routine. Improvements in artificial intelligence and energy storage will likely be necessary before drones can operate safely (and profitably) in delivery contexts.

Wheeled robots may be easy to deploy but are not effective for delivering outside a few narrow contexts (such as to buildings at sidewalk level or to buildings with sidewalk-accessible elevators). It is unclear whether delivery robots will be safe and legal to operate in all contexts in which suppliers hope to deploy them; thus, new regulations will likely emerge. And robo-delivery services will need to compete against ones that use humans for the same tasks, with seemingly ever-increasing efficiency.

Impacts/Disruptions

Most of the early industry focus on robo delivery appears to be on solving the most difficult problems, such as how to move a cold beer from a distribution center to a customer's hand using only robots. Robo delivery to loading docks, office mailrooms, and the like may be far easier to implement from a technology perspective but might be attracting less investment because of the business-related complexities of such an endeavor. Meanwhile, a number of new companies are working to make it easier for robots to deliver to people who live in large multidwelling buildings via offering automated package lockers for such buildings' lobbies. Rather than putting a cold beer in a customer's hand, a future robot deliverer could simply place the beer into a refrigerated cubby in the package locker in the customer's building, while also delivering many other items to the locker at the same time.

Scale of Impact	Low	Medium	**High**

Time of Impact	Now	**5 Years**	**10 Years**	15 Years

Opportunities in the following industry areas:
Automotive, urban planning, logistics, manufacturing, retail, real estate, energy storage, batteries, drones

Relevant to the following Explorer Technology Areas:
• Connected Cars • Artificial Intelligence • Connected Homes • Energy Storage • Mobile Communications • Pervasive Computing • Robotics • User Interfaces

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Connected Cars

By Katerie Whitman (kwhitman@sbi-i.com)

Crowdsourced Delivery

Why is this topic significant? Many companies have been offering services to connect people (and other companies) who wish to send packages to each other with people (and other companies) who are interested in delivering those packages. Connected cars are essential parts of such enterprises and their plans.

Description

Uber, Didi, and other crowdsourced taxi services are essentially in the business of connecting individuals with different—but compatible—desires: People who desire to go from one place to another by car and drivers who need flexible employment opportunities. Now, a group of companies—including Uber and Didi—are working to do the same with package delivery. Both companies have services that allow end users to order food from local restaurants and have drivers for the service deliver the food. Parallel services specialize in delivering parcels (that contain nonperishable items) from a sender to a receiver.

Uber and Didi have a great many competitors in both the food-delivery and the parcel-delivery businesses, including start-up companies such as DoorDash that specialize in only one delivery type (food from restaurants, in DoorDash's case). In most cases, the "app workers" who actually perform deliveries do so using their own vehicles, relying on the same kinds of connected-car technologies that are in use in crowdsourced-taxi applications. Some services specialize in facilitating courier-type deliveries (which often involve two-wheeled vehicles of various kinds), whereas others specialize more in delivering goods between points further up the logistics chain (for example, from a port to a warehouse's loading dock). In some cases, such as with Amazon, the companies that need product deliveries done are running their own crowdsourced-delivery platforms, and app workers for those platforms often use small delivery vans that they own or lease for such purposes.

Implications

As is common with crowdsourced-taxi services, Current crowdsourced-delivery services apparently lose large amounts of money on each delivery and make up the losses by burning through venture capital. And yet, investors continue to pump money into these businesses, largely on the basis of presumptions that one of the many competitors in crowdsourced-taxi and crowdsourced-delivery

services will come to dominate their market and will then be able to raise prices over time and start collecting huge profits from customers who have few other options. Another assumption appears to be that robots and driverless cars will eventually help the new delivery services reduce costs so much that they will outcompete all other such services. Both of these ideas are highly speculative and place crowdsourced-delivery companies in an unstable market position: Either they lose money at a rate that may be unsustainable, or they lose market share to competitors that are willing to lose more money.

Impacts/Disruptions

It is certainly possible that at least some crowdsourced-delivery enterprises will weather the current market instability and end up surviving. But future prospects for the current crop of online-to-offline services and their business models are far from assured. Nevertheless, the idea that "you happen to be going from X location to Y location right now anyway, so why not get paid a little money to bring this package along with you?" is fundamentally a sound one that seems achievable with extensions of today's technologies. This concept may become the future of crowdsourced delivery.

Scale of Impact	Low	Medium	**High**

Time of Impact	Now	**5 Years**	10 Years	15 Years

Opportunities in the following industry areas:
Automotive, transportation, urban planning, logistics, telework, retail, hospitality

Relevant to the following Explorer Technology Areas:
• Connected Cars • Artificial Intelligence • Big Data • Mobile Communications • Pervasive Computing
• Robotics • User Interfaces

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EXPLORER

Viewpoints

August 2017

Solid-State Microsensors

By Michael Gold (mgold@sbi-i.com)

Sensing with Ultrawideband Radar

Why is this topic significant? Ultrawideband radar has potential to sense through walls and detect subtle movements, including a person's vital signs. The technology is not new but is seeing some progress toward increased commercialization.

Description

Some developers make use of ultrawideband (UWB) technology for location sensing, often with help from active radio-frequency-identification tags that transmit UWB signals in the form of extremely short pulses. Such pulses can be ideal for discriminating radio and radar reflections in environments that are electromagnetically noisy and that suffer from multipath interference. Alereon and Ubisense are among the players that supply UWB-based real-time location systems for warehouses and factories.

One UWB radar product, from Preview Radar Systems, senses obstacles; the product seems to compete effectively in a niche market for construction-equipment radar that is dominated by non-UWB sensors. In contrast, a unique prosumer-grade product comes from Move 'N See, which supplies a motorized camera mount, a set of UWB beacons, and a wrist-worn UWB transmitter. The robotic camera mount triangulates the position of, for example, a horse rider, skateboarder, or tennis player; in response, the camera automatically pans to keep the subject centered and zooms as the subject moves closer to or farther from the camera.

Developers of UWB radar have also sought to commercialize the technology for detecting presence of people (who don't wear a tag) and their breathing movements. Norwegian start-up Novelda received $12 million in venture-capital investments during late 2016 and has a number of business-development initiatives in place. Notably, it supplies chips to Shanghai Megahealth, which recently received approval from medical-device regulators in China to sell a UWB radar device for in-home preliminary diagnoses of sleep apnea. Such diagnoses typically involve complex equipment and an overnight stay at a sleep clinic; the new device promises to make such visits unnecessary for some people. The bedside sensor quantifies small movements and detects signs of irregular breathing.

Implications

No one knows whether UWB radar will ever enable large-scale markets. But despite years of developments, the range of potential commercial applications still remains remarkably large. Novelda's chips reportedly count people in the Gangnam subway station in Seoul, South Korea; the company envisions use of UWB radar in security systems. Another company, Time Domain, is promoting use of UWB positioning technology for drones and robots. Generally, UWB radar has untapped potential to "see through walls" and could thus be of use to building remodelers—especially property owners seeking to improve the energy efficiency of old buildings, whose construction details are often mysterious. Perhaps most interesting of all, various researchers have demonstrated use of UWB radar for monitoring heart activity without physically contacting a person's chest.

Impacts/Disruptions

Cars with advanced cruise controls might need to detect if drivers remain vigilant and ready to resume control of a vehicle on a few seconds' notice. A sensor-fusion system that includes UWB radar might be helpful for monitoring drivers of semiautonomous cars. In-dash UWB radar might even be able to monitor whether a driver is experiencing a heart attack or other serious cardiac event (assuming a carmaker truly wants to know this information). On the exterior of such cars, UWB radar might supplement existing narrowband radars. During recent years, South Korean researchers reported progress toward use of UWB to detect fast-moving nearby objects; some of the researchers also applied for a related patent.

Scale of Impact	Low	**Medium**		High
Time of Impact	Now	**5 Years**	**10 Years**	15 Years

Opportunities in the following industry areas:
Electronics manufacturing, electromagnetics research, robotics, transportation, construction, film and TV production, sleep medicine, warehouse and factory operations

Relevant to the following Explorer Technology Areas:
- Solid-State Microsensors • Connected Cars • Mobile Communications • Pervasive Computing
- RFID Technologies • User Interfaces

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Solid-State Microsensors

By Michael Gold (mgold@sbi-i.com)

Update on Stacked-Chip Image Sensors

Why is this topic significant? Image sensors were the first instances of high-volume production of stacked pairs of chips that are bonded directly together, one on top of another. Recent smartphone cameras are the first instances of mass-produced three-level stacks. Developers might be blazing new trails that affect other types of sensors and that generally aid in cramming more capabilities into miniaturized products.

Description

The April 2013 Viewpoints describes how Sony pioneered the commercialization of smartphone cameras consisting of two stacked chips: one for sensing and the other for signal processing. The chips are in direct contact with one another, with no interposing connectors. OmniVision and Samsung subsequently began mass-producing similar stacked-chip complementary metal-oxide-semiconductor image sensors for smartphones, and SMIC recently indicated it will do likewise. During recent months, reverse-engineering specialist TechInsights reported that "two-die stacks...have emerged as the dominant configuration for leading smartphone camera chips." The chips serve as the main cameras in flagship phones from Apple, Google, and Samsung.

At a February 2017 technical conference, Sony published details of new cameras consisting of three-chip stacks, and during April the company began selling smartphones that use the components. The smartphones have exceptional slow-motion capture capabilities at 960 frames per second and at HD (720p) resolution. The camera packages are apparently the first-ever commercial electronic components that consist of three chips that are stacked one on top of the other. A memory (dynamic random-access-memory) die is sandwiched between an image-sensor die and an image-processor die.

Some people use terms such as *3D chips* or *2.5D chips* to describe current developments, which mostly affect sensors for now. Although low-production-volume stacked sensors have been available for almost ten years, Sony was the first to achieve high-volume mass production. By 2016, STMicroelectronics reported that it had started mass-producing microelectromechanical-systems inertial-sensor dice that reside directly on signal-processing dice.

Implications

Formerly, users seemed happy to have reasonable-quality images to preserve personal memories. But today's social-media trends motivate influential users and their followers to shoot "Instagram worthy," high-impact images and short videos. Smartphone makers are happy to oblige, and they need pathways toward image-processing improvements in coming years. For example, a triple chip's high-data-rate internal interfaces could in theory help users capture crisp images of fast-action scenes in low-light conditions, such as a game of Frisbee at twilight.

Also, image-sensor road maps might include stacked chips that use silicon-on-insulator substrates for the image-processing layer. Such image processors can run computational-photography software that helps close the performance gap between smartphone cameras and dedicated video cameras having optical zoom, macro lenses, and telephoto lenses. Future stacked chips might also include other types of imaging sensors, such as radar chips for automated vehicles and depth cameras for augmented-reality eyewear.

Impacts/Disruptions

Desires to cram as many features and capabilities as possible in as little circuit-board area as possible motivate increased use of three-dimensional structures—analogous to a dense city that has nowhere to build but up. Stacking prepackaged chips is a traditional but somewhat costly practice that has limited space-saving advantages. Economies of scale in the smartphone business could cause direct die-to-die stacking to become cost-effective for purposes beyond sensors, as manufacturers seek ways to improve products while maintaining existing form factors (such as for wearables) and produce highly miniaturized system-on-chip stacks (such as for wireless security cameras and other Internet of Things devices).

Scale of Impact	Low	**Medium**	High	
Time of Impact	Now	**5 Years**	**10 Years**	15 Years

Opportunities in the following industry areas:
Electronics manufacturing, semiconductor manufacturing, semiconductor materials, photography, image-processing software, security and surveillance

Relevant to the following Explorer Technology Areas:
• Solid-State Microsensors • 3D Printing • Connected Cars • MEMS/Micromachining • Mobile Communications • Portable Electronic Devices • Robotics • User Interfaces

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August 2017

P1101

Solar-Power Enablers

By Susan Leiby (Send us feedback.)

New technologies are enabling innovative ways to use and store solar power and to reduce the cost of operating solar systems.

Abstracts in this Pattern:

SC-2017-07-05-012 on trading

SC-2017-07-05-063 on automation technology

SC-2017-07-05-026 on energy storage

Solar power is an increasingly competitive energy that is seeing record use in many countries. A growing number of homes and businesses are meeting more of their energy demand with solar power, and new tools are giving these producers more control over the power they generate. The Brooklyn Microgrid (New York, New York) is a growing energy co-op that already connects about 50 homeowners and businesses through a blockchain-based virtual trading platform. Solar-energy producers can sell excess-electricity credits to buyers within the group. Start-up LO3 Energy (New York, New York) worked with Siemens (Berlin and Munich, Germany) to develop the microgrid, which aims to cut out electric utilities entirely and provide a secure platform for transactions.

Automation technologies—including algorithms, drones, and robots—are helping to accelerate the development of lower-cost solar plants. SunPower Corporation (San Jose, California) is using drones to map sites for its new large-scale Oasis solar plants and custom cloud-based software to identify solar-panel configurations that maximize the plants' electrical output and return on investment. SunPower claims that using these technologies enables engineers to design solar plants substantially faster and that Oasis solar plants can generate more energy than can typical solar plants. The Oasis plants also feature robotic solar-panel-cleaning technology, and SunPower claims the cleaning robots use less water and finish cleaning faster than do manual cleaning methods.

The rapidly increasing use of solar power has created a need for new energy-storage solutions to help integrate increasing levels of intermittent power into the grid and off-grid systems. Scientists from the University of Southern California (Los Angeles, California) and the National Renewable Energy Laboratory (Golden, Colorado) recently developed a new type of solar cell that generates electricity and then performs electrolysis of water to generate hydrogen, which is a transportable fuel that has potential to become an important vehicle for energy storage. The researchers created a gallium arsenide–based solar cell that uses only a small amount of the expensive gallium arsenide material and avoids some of the problems common to solar-cell electrolysis.

Signals of Change related to the topic:

SoC919 — Advancing Renewable Energy

SoC848 — Fossil-Fuel Headwinds

SoC746 — …Power of Solar Energy

Patterns related to the topic:

P0983 — Tackling Fossil Energy…

P0969 — The Age of Solar Energy

P0959 — …Renewable-Energy Use

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EXPLORER

Viewpoints

August 2017

Pervasive Computing

By Sean R. Barulich (sbarulich@sbi-i.com)

Ultrareliable Low-Latency Communications

Why is this topic significant? Ultrareliable low-latency communications can expand capabilities and content for mobile devices, vehicles, and mixed-reality headsets.

Description

The 3rd Generation Partnership Project and the International Telecommunication Union (ITU) are developing proposed standards for 5G (fifth-generation) New Radio access technologies. These standards include the goal of ultrareliable low-latency communications (URLLC). The ITU specifies that under certain conditions, URLLC systems must be capable of delivering a message 1 millisecond after a user sends it. The ITU further suggests that low-latency communications should make it possible for haptic, audio, video, and robotic systems to respond with "imperceptible time lag." Another requirement of URLLC is high reliability, such that no more than 1 in 10,000 data packets fails in transmission. This standard has potential to enable use of 5G networks in safety-critical applications such as autonomous-vehicle forward-collision warnings, vehicle-to-infrastructure communications, and cloud-based guidance for drones.

Researchers from South Korea, Finland, and the United States are looking to improve vehicle-to-vehicle communications for URLLC. In a recent simulation that grouped vehicles according to their proximity and that made use of algorithmic optimizations, the team was able to reduce latency and power use dramatically. Previously during 2017, researchers from Lund University explored alternative methods to reduce latency to establish a "tactile internet" that supports near-real-time telepresence. The researchers employed a simulated massive multiple-input, multiple-output antenna experiment to reduce latency and understand technical trade-offs in future systems. The group's findings suggest that a network will experience a limit to "the number of simultaneously supportable devices" that fulfill the requirements of URLLC.

Implications

Low-latency communications has the potential to enable a variety of technologies for both consumers and industry. For future autonomous vehicles, URLLC introduces rapid multipoint communication for vehicle-to-vehicle and vehicle-to-infrastructure communications. In theory, a cloud computer could make a safety-critical decision, and 1 millisecond later, an autonomous car would execute the decision. The telecommunications industry clearly wants to play such roles in communication services for transportation, robotics, and drones. Although 5G and low-latency connections will certainly play important roles in transportation, if and how motor industries would rely on URLLC for real-time maneuvers is still unclear. Apparently all driverless-car developers—dozens of organizations—rely exclusively on onboard computers for such purposes.

Reliable low-latency communications may also enable digital and robotic technologies to sync up with human physiological response times. Cloud and edge computers would generate real-time sensory feedback, including texture and other haptic sensations when interacting with augmented reality (AR), virtual reality (VR), and telepresence. High-resolution video, audio, gesture controls, and even remote robots would operate in sync.

Impacts/Disruptions

Researchers' addressing of challenges in deploying URLLC and 5G communications could disrupt current autonomous-vehicle roadmaps as the researchers enable multipoint communication. Further attention would shift to AR and VR. For example, if URLLC can let computers control wearable devices, developers could reduce size and weight of electronic eyewear to become suitable for all-day use. In that case, cloud AR may see increased roles in everyday life and might increase productivity in professional applications.

Although apparently 5G will eventually see deployment, no guarantee exists that URLLC will necessarily succeed. Low-latency communications may be too expensive to implement broadly for consumers and may instead be reserved for high-value applications. Such an application could include URLLC for emergency services, remote surgery, and the military.

Scale of Impact	Low	Medium	**High**

Time of Impact	Now	**5 Years**	10 Years	15 Years

Opportunities in the following industry areas:
Electronics manufacturers, telecommunications, IoT, video and audio streaming, virtual reality, augmented reality

Relevant to the following Explorer Technology Areas:
• Pervasive Computing • Artificial Intelligence • Connected Cars • Mobile Communications • Portable Electronic Devices • Robotics • User Interfaces

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Pervasive Computing

By David Strachan-Olson (SBI Analyst: Sean R. Barulich, sbarulich@sbi-i.com)
Strachan-Olson is a technology analyst with Strategic Business Insights.

Spread of End-to-End Encrypted Communications

Why is this topic significant? The proliferation of end-to-end encryption in messaging applications has added to ongoing debates between companies and government agencies about encryption's impact on national security, criminal investigations, and personal transparency and security.

Description

Encryption helps keep sensitive communications such as bank and e-commerce transactions as well as information on devices secure. Messaging applications increasingly support end-to-end encryption (E2EE) for communication between users. A typical messaging application may encrypt a message as it travels from user A's client to the server and from the server to user B's client, but the server may store the unencrypted message. With E2EE, the information is encrypted in a manner in which only user B's client knows the key to decrypt the message from user A. This encryption prevents any entity—including service providers, cybersecurity agencies, hackers, and even the platform's developers and operators—from viewing the content of the communications.

For some years, E2EE systems saw use by only a few niche groups of users. More recently, messaging services with many users have started supporting E2EE. In 2016, WhatsApp, which has more than a billion users worldwide, released an update that made every conversation support E2EE. Other notable applications that support E2EE (but not always by default) include iMessage, Facebook's Messenger, Telegram, Signal, and Confide. Additionally, numerous email clients support E2EE.

Implications

As E2EE messaging applications have become more popular, numerous government officials have begun to scrutinize such applications because of their potential impacts on national security and criminal investigations. E2EE can also interfere with companies' efforts to comply with government requests for user communications, because the company is incapable of decoding the

communications. Criticism of E2EE has increased as investigations have revealed that terrorists recently used E2EE messaging while planning attacks or just before such attacks, apparently including the March 2017 attack on London, England's Westminster Bridge.

Numerous government officials in multiple countries are calling for legislation that would require companies to implement systems that allow government agencies to access these communications. Proponents for such measures claim that they will help improve national security by helping government agencies gather intelligence, find accomplices, and prevent attacks. Opponents of such measures believe that hackers could find and exploit "backdoors," risking individuals' and organizations' security. Users of E2EE messengers may reside in countries with limited individual protections, and government methods to circumnavigate encryption could put them in danger. Terrorists and rogue actors could move to other E2EE messengers that cannot be compelled by governments or develop their own system from open-source software.

Opponents generally believe that encrypted communications are vital to protect the rights and security of individuals from abuse by governments, companies, and hackers. Some opponents also argue that governments already have the capabilities to bypass E2EE effectively by targeting individual devices and the on-device clients of messaging services rather than the communications directly.

Impacts/Disruptions

As discussions surrounding encryption of personal data and communications continue to evolve, some companies are beginning to think of data as a liability rather than an asset because they encourage hacking and inquiry by government agencies. Companies with business models that do not require data analytics may prefer to store user data on company servers in an encrypted format that only the user can decrypt. Potential services that could use this method include messaging, cloud backups, cloud storage, and health monitoring.

Scale of Impact	Low	**Medium**	High	
Time of Impact	**Now**	**5 Years**	10 Years	15 Years

Opportunities in the following industry areas:
Messaging applications, web services, law enforcement, defense and security, open-source software

Relevant to the following Explorer Technology Areas:
• Pervasive Computing • Artificial Intelligence • Big Data • Mobile Communications