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the institute

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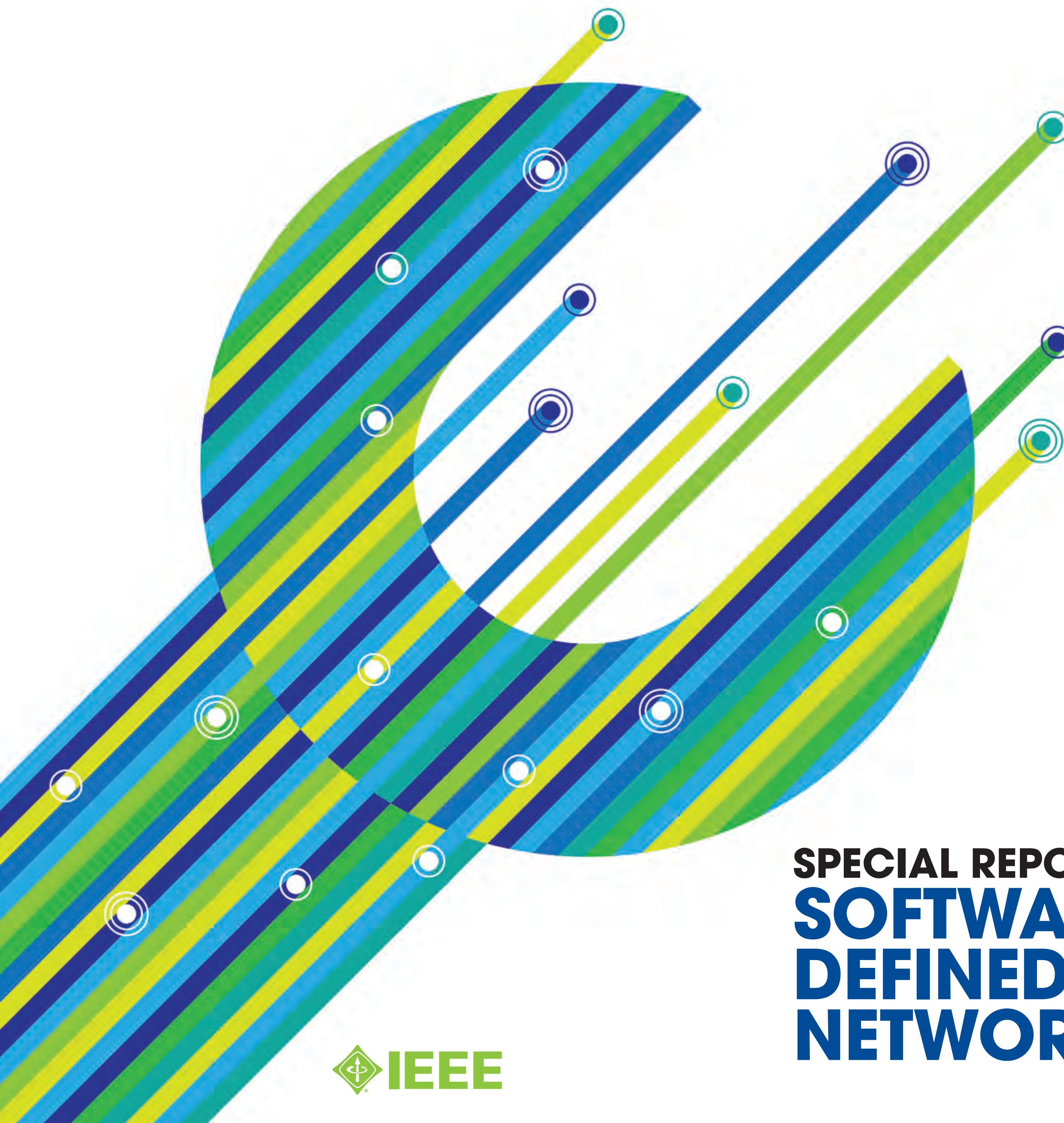
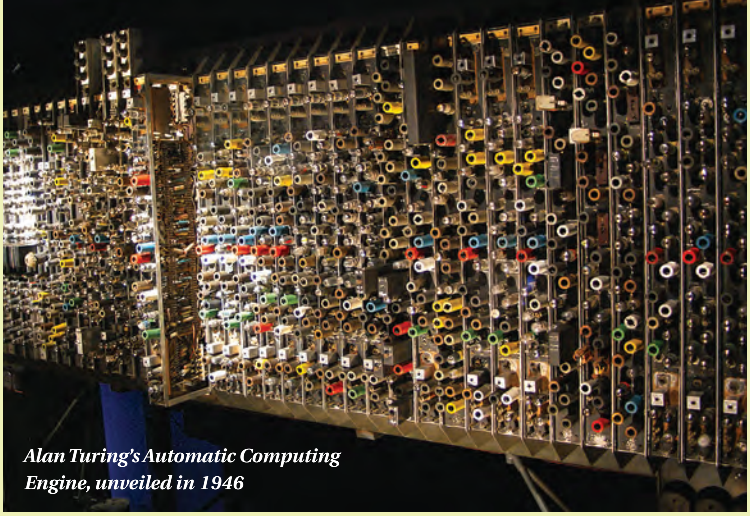


SPECIAL REPORT

SOFTWARE-DEFINED NETWORKS

IEEE



Alan Turing's Automatic Computing Engine, unveiled in 1946

December

5
1914: Birth date of **Charles A. Meyer**, founder and first chair of the Institute of Radio Engineers' Professional Group on Engineering Writing and Speech. (The IRE was one of IEEE's predecessor societies.)

17
1824: Birth date of **John Kerr**, the physicist who discovered the effect of electrical and magnetic fields on light—now known as the Kerr effect.

24
1956: Birth date of **Steve Kirsch**, inventor of the optical mouse.

28
1895: Inventors Auguste and Louis Lumière debut their **cinématographe, the first motion-picture apparatus** [above], to a paying audience.

29
1952: The Sonotone 1010, the **first commercial transistorized hearing aid**, hits the market. It was developed and manufactured by Sonotone Corp. of Elmsford, N.Y.

January

8
1918: U.S. President Woodrow Wilson's **14 Points address to Congress is transmitted to Europe** by the New Brunswick Naval Radio Station, in New Jersey. Built in 1913 by the Marconi Wireless Telegraph Co., the station was the main link between the United States and Europe during World War I.

15
1803: Birth date of **Heinrich Daniel Ruhmkorff**, a German engineer who invented the high-voltage induction coil that bears his name.

22
1775: Birth date of **André-Marie Ampère** [below], considered the father of electromagnetism. The unit for measuring electric current—the ampere—is named after him.

23
1909: One of IRE's founding organizations, **the Wireless Institute**, is formed in New York City.

25
1878: Birth date of **Ernst Frederick Werner Alexanderson,** inventor of a radio alternator, a high-power radio-frequency source. It was named an IEEE Milestone in 1992.

February

4–9
IEEE Meeting Series, in New Orleans [above].

7
1920: Birth date of **An Wang**, a pioneer of ferrite core memory and founder of Wang Laboratories, a developer of early computers, in Cambridge, Mass.

19
1946: Alan Turing delivers the design for the **Automatic Computing Engine** [top], an early electronic stored-program computer.

29
1860: Birth date of **Herman Hollerith**, inventor of punched-card equipment for data processing and founder of the Tabulating Machine Co., which became IBM.

See our interactive calendar for photos and videos of these important dates in engineering history at http://theinstitute.ieee.org/briefings/calendar. Historical events are provided by the IEEE History Center. IEEE events are indicated in red.

FROM TOP: MARK DUNN/ALAMY; ISTOCKPHOTO; SSPL/GETTY IMAGES; DE AGOSTINI/GETTY IMAGES

BRIEFINGS

Shoop Is Chosen as President-Elect

IEEE FELLOW Barry L. Shoop has been chosen as 2015 IEEE president-elect. He will begin serving as IEEE president on 1 January 2016.

Shoop received 15,972 votes in this year's election. Of the other candidates for president-elect, Fellow Tariq S. Durrani garnered 14,831 votes and Life Fellow Frederick C. Mintzer received 14,056. The results were made official when the IEEE Board of Directors accepted the Tellers Committee report at its November meeting, in New Brunswick, N.J.

Shoop is professor of electrical engineering and head of the electrical engineering and computer science department at the U.S. Military Academy, in West Point, N.Y. He is responsible for a department serving 2,300 students annually.

He joined the faculty of West Point in 1993 and has held a number of leadership positions, including director of the electrical engineering program and the Photonics Research Center. While on sabbatical in 2006 and 2007, he served as chief scientist for the U.S. Department of Defense Joint Improvised Explosive Device Defeat Organization, a US $4.5 billion program addressing the IED problem worldwide.

A fellow of the Optical Society of America and the International Society for Optics and Photonics (SPIE), Shoop received the 2008 OSA Robert E. Hopkins Leadership Award, the 2013 SPIE Educator Award, and the 2013 IEEE Haraden Pratt Award.

He served on the IEEE Board of Directors from 2006 to 2010 and was 2010 vice president of IEEE Member and Geographic Activities, IEEE secretary in 2008 and 2009, and Region 1 director in 2006 and 2007. As leader of the IEEE Enterprise Engineering team in 2006 and 2007, he led the transformation of the IEEE Regional Activities Board into the IEEE Member and Geographic Activities Board. He has served on the IEEE Executive, Strategic Planning, New Initiatives, and Audit committees.

—Amanda Davis

Five Ways to Improve IEEE

HERE ARE THE TOP FIVE recommendations for improving IEEE, worded as they were voted upon by the 294 primary section delegates at the IEEE Sections Congress, held 22–24 August in Amsterdam.

- Include free access to the IEEE [Xplore] Digital Library as a member benefit. Promote other IEEE services and products based on their usage and preferences (adopt Google business model).
- Develop an incentive and recognition program for companies that invest in full or partial support of their employees' IEEE membership dues.
- Introduce loyalty rewards such as publication access, conference fees, [and] standards for continued membership.
- Provide a tool to build, promote, record, host, and broadcast technical events at the local level and make them available to IEEE members.
- Enhance vTools for better usability by volunteers and provide a training program to the sections.

— Kathy Pretz

COVER: CARL DETORRES; LEFT: J. PELLINO; RIGHT: ISTOCKPHOTO

Herz Award Goes to Fran Zappulla

FRAN ZAPPULLA has been chosen to receive the 2014 IEEE Eric Herz Outstanding Staff Member Award for "outstanding leadership in the success of IEEE publications." She was presented with the award in November at the IEEE Meeting Series, in New Brunswick, N.J.

Zappulla [right] has been senior director of publishing operations, in Piscataway, N.J., since 1999. She joined IEEE in 1989 as director of art and production for *IEEE Spectrum*. The following year, she was named operations director of the magazine, and in 1993 she became associate publisher of the magazine as well as the IEEE magazine and newsletter department. She was promoted in 1996 to director of IEEE periodicals, a position she held until 1999.

In her 25 years with the organization, she has helped IEEE's publishing operations shift from print to electronic publishing, significantly shortened the time it takes for research papers to be published, and reduced editorial and production costs.

The IEEE Board of Directors created the Herz Award in 2005 to honor longtime volunteer Eric Herz, who served in many capacities, including IEEE general manager and executive director. The award recognizes a present or past full-time staff member of the IEEE with at least 10 years of service for demonstrated contributions over a long period of time.

The nomination deadline for the 2015 Herz Award is 31 January. For more information, visit http://www.ieee.org/about/awards/recognitions_herz.html. —*A.D.*

IEEE to Launch Eight New Publications

EIGHT ELECTRONIC IEEE publications are scheduled to debut next year. They will be available in the IEEE Xplore Digital Library.

IEEE Transactions on Cognitive Communications and Networking will explore applications of learning, memory, and adaptive approaches to the design of communications systems. It will also cover artificial intelligence, software-defined networking, and cognitive radio.

Another journal, *IEEE Transactions on Molecular, Biological, and Multi-Scale Communications,* will cover the principles, design, and analysis of communications systems that rely on principles of physics beyond classical electromagnetism. That includes molecular, quantum, and other physical, chemical, and biological techniques.

IEEE Transactions on Multi-Scale Computing Systems will publish research on micro- and nanoscale computing systems and data-processing technologies.

LEFT: IEEE; RIGHT: ISTOCKPHOTO

IEEE Transactions on Transportation Electrification will focus on components, subsystems, standards, and grid-interface technologies related to power and energy conversion, propulsion, and actuation for electrified vehicles.

IEEE Transactions on Big Data will deal with analytics, infrastructure, standards, performance analysis, intelligence, security, privacy, and scientific discovery.

IEEE Systems, Man, and Cybernetics Magazine will not only include articles on human-machine interfaces and systems engineering but will also highlight the IEEE Systems, Man, and Cybernetics Society's educational programs, conferences, and other activities.

Research published in *IEEE Transactions on Computational Imaging* is expected to include advanced algorithms and mathematical techniques, model-based data inversion, methods for image and signal recovery from sparse and incomplete data, and software and hardware for efficient computation in imaging systems.

And look to *IEEE Transactions on Signal and Information Processing Over Networks* for papers on algorithms for filtering, detection, estimation, adaptation, and learning; model selection; data fusion; and applications of distributed signal processing. *—A.D.*

CORRECTION

"Census and Sensibility" [September, p. 9] incorrectly stated that William the Conqueror defeated Edward the Confessor. He defeated the English king, Harold Godwinson.

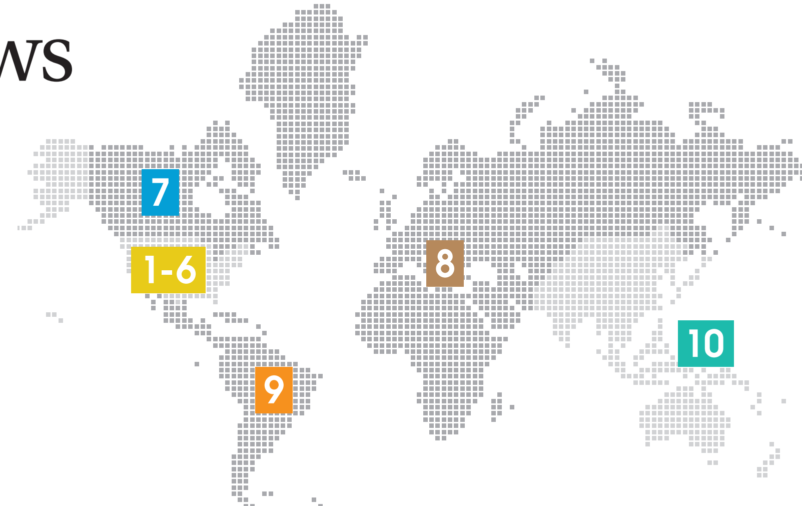
Online

Available 8 December at theinstitute.ieee.org

TECH HISTORY
An IEEE Milestone honors the first flight in which the pilot relied solely on instruments.

ACHIEVEMENTS
Three IEEE members have been recognized by other organizations.

Region News



REGION 1 — NORTHEASTERN UNITED STATES

■ **New Jersey Coast Section** forms IEEE Power & Energy Society chapter.

■ **Green Mountain (Vt.) Section** forms IEEE Electron Devices Society chapter.

■ **Providence (R.I.) Section** forms joint chapter of IEEE Oceanic Engineering and Signal Processing societies.

REGION 4 — CENTRAL UNITED STATES

■ Student branch at **Indiana University–Purdue University, Indianapolis,** forms IEEE Industry Applications Society chapter.

■ Student branch at **University of Illinois, Urbana-Champaign,** forms joint chapter of IEEE Power & Energy, Power Electronics, and Industry Applications societies.

REGION 5 — SOUTHWESTERN UNITED STATES

■ Student branch formed at **University of Houston.**

REGION 6 — WESTERN UNITED STATES

■ **Coastal Los Angeles Section** forms IEEE Life Members affinity group.

■ **Metropolitan Los Angeles Section** forms IEEE Photonics Society chapter.

REGION 7 — CANADA

■ **Kingston (Ontario) Section** forms joint chapter of IEEE Antennas and Propagation and IEEE Microwave Theory and Techniques societies.

REGION 8 — EUROPE, MIDDLE EAST, AND AFRICA

■ Student branch formed at **University of Boumerdes, Algeria.**

■ **Bosnia and Herzegovina Section** forms joint chapter of IEEE Industry Applications and Power Electronics societies.

■ Student branch at **University of Sarajevo,** in Bosnia and Herzegovina, forms IEEE Communications Society chapter.

■ Student branch at **Aalborg University, Denmark,** forms IEEE Industry Applications Society chapter.

■ Student branch at **Alexandria University, Egypt,** forms IEEE Solid-State Circuits Society chapter.

■ Student branch formed at **British University, Cairo.**

■ Student branch formed at **University of Warwick, Coventry, England.**

■ Student branch at **University of Bordeaux, France,** forms IEEE Microwave Theory and Techniques Society chapter.

■ Student branch formed at **Chemnitz University of Technology, Germany.**

■ Student branch formed at **Sikkim Manipal University, Accra, Ghana.**

■ **Greece Section** forms joint chapter of IEEE Antennas and Propagation, Electron Devices, and Microwave Theory and Techniques societies.

■ Student branch at **Aristotle University of Thessaloniki, Greece,** forms IEEE Engineering in Medicine and Biology Society chapter.

■ Student branch formed at **University of Human Development, Sulaymaniyah, Iraq.**

■ **Lebanon Section** forms IEEE Engineering in Medicine and Biology Society chapter.

■ **Norway Section** forms IEEE Young Professionals affinity group.

REGION 9 — LATIN AMERICA

■ Student branch at the **Universidade of Brasília** forms IEEE Aerospace and Electronic Systems and IEEE Engineering in Medicine and Biology society chapters.

■ Student branches in Colombia at **Universidad Nacional de Colombia, Manizales,** and **Universidad de Nariño** form IEEE Women in Engineering (WIE) affinity groups.

■ Student branch formed at **Universidad del Caribe, Santo Domingo, Dominican Republic.**

■ Student branch formed at **Universidad San Francisco de Quito, Ecuador.**

■ **Honduras Section** forms IEEE WIE affinity group.

■ Student branch formed at **Universidad Tecnológica Centroamericana, Tegucigalpa, Honduras.**

■ **Querétaro (Mexico) Section** forms IEEE Systems, Man, and Cybernetics Society chapter.

■ Student branch at **Universidad Católica Santo Toribio de Mogrovejo, Chiclayo, Peru,** forms IEEE Industry Applications Society chapter.

REGION 10 — ASIA AND PACIFIC

■ **Western Australia Section** forms joint chapter of IEEE Computational Intelligence and IEEE Robotics and Automation societies.

■ **Beijing Section** forms IEEE Robotics and Automation Society chapter.

■ **Wuhan (China) Section** forms IEEE Control Systems Society chapter.

■ **Xian (China) Section** forms IEEE Electromagnetic Compatibility Society chapter.

■ **Bangalore (India) Section** forms IEEE Robotics and Automation Society chapter.

■ **Hyderabad** and **Madras sections (India)** form IEEE Computational Intelligence Society chapters.

■ **Kansai (Japan) Section** forms IEEE WIE affinity group.

■ **Korea Council** forms IEEE Oceanic Engineering Society chapter.

■ **Malaysia Section** forms IEEE Computational Intelligence Society chapter.

■ **New Zealand Central Section** forms IEEE Computational Intelligence Society chapter.

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SPECIAL REPORT:

SOFTWARE-DEFINED NETWORKS

WITH ADVANCES in IT and cloud computing, the increasing number of intelligent machines, and the advent of the Internet of Things, the traffic on telecommunications networks is expected to skyrocket. Meanwhile, hardware costs are tumbling, and more and more open-source software is available. It's clear that a change is needed in how networks are designed and operated.

Enter software-defined networks. SDNs could transform network architecture and service provisioning and delivery. They are networks of equipment that decouple hardware (which does such things as forwarding IP packets) from software (the control plane that carries signaling traffic for routing through the network devices). SDNs may run such software either in the cloud or in clusters of distributed IT servers as well as in the equipment, which until recently was the only option.

SDN technology will support the changing nature of future networks while taking advantage of savings in equipment investment and operating costs. That will give operators the agility to create or program highly flexible and dynamic networks capable of integrating and monitoring terminals, intelligent machines, and smart devices and even to control robots to support innovative services. The advent of SDNs is going to affect just about every part of our lives.

Through its Software Defined Networks Initiative, IEEE is working on many fronts to explore the benefits of SDNs and network functions virtualization, which is often paired with SDNs. The NFV concept, which has been around the computing industry since the 1960s, applies CPU virtualization and other cloud-computing technologies to migrate network functions from dedicated hardware to virtual machines running on general-purpose hardware.

The initiative was launched in May 2013 under the IEEE Future Directions Committee, the organization's R&D arm. Initiative committees are working on conferences, education modules, standards, publications, and proof-of-concept models.

Our special report provides an overview of SDNs, including a discussion of the concept of softwarization of everything [see p. 8] and the skills needed to design and operate the new networks [see p. 9]. And we've profiled IEEE Member Antonio Manzalini, chair of the IEEE SDN Initiative [see p. 16].

This issue also highlights IEEE products, standards, and conferences that can help members become more knowledgeable about the transformative SDN architecture.

Reinventing Communications Networks

IEEE sets the stage for software-defined networks BY **KATHY PRETZ**

TODAY'S telecommunications networks are rather static and complex, involving equipment such as transmission nodes, routers, switches, and middleboxes, including firewalls, network address translators, and intrusion-detection systems. The IP packet traffic that flows from them—and where it goes —is controlled by management and control rules and policies. Management covers faults, configuration, accounting, performance, and security. Current networks are rather static and inflexible, and this makes it difficult to cope with future dynamic service demands and the need to quickly introduce innovative new technology.

Add to that advances in technology and the decreasing cost of IT and ultrabroadband connectivity as well as the Internet of Things, with its billions of new devices laden with sensors. And then there is the growing availability of relatively inexpensive open-source software and the falling price of hardware—both calling for networks to become more flexible and easier to upgrade.

Many experts, including IEEE's, say much can be gained from the

CARL DETORRES (2)

flexibility of software-defined networks (SDNs). The term refers to networks of equipment that separate the data plane (in which hardware does things such as forwarding IP packets toward their destination) from the control plane (where, for example, software is in charge of routing and traffic engineering). Moreover, in SDN the control software is not necessarily executed in the equipment but potentially in the cloud or in standard processing resources, such as IT servers.

A key aspect of SDNs is that they provide an array of abstractions and application programming interfaces (APIs) to program and control the functions and the services of network resources.

When talking about SDNs, virtualization is often mentioned. Virtualization is about creating logical resources, which are pieces of software running on a hardware host and emulating hardware capabilities, such as an x86 CPU (x86 is a family of backward-compatible, instruction-set architectures based on the workhorse Intel 8086 CPU). The novelty here is that the functions of most equipment, including the middleboxes, could be virtualized, incorporated, and moved as needed to various locations in the network.

SDNs and virtualization are not new concepts, but thanks to improved performance and lower costs, will soon help reinvent network and service architectures, experts say.

"Future networks will rely more and more on software—which will accelerate the pace of innovation," says IEEE Member Antonio Manzalini, chair of the IEEE Software Defined Networks Initiative. SDNs give operators "the agility of a highly flexible and dynamic network, integrating IT and networking resources, and are capable of hooking together at the edge the huge number of terminals, machines, smart things, and even robots," Manzalini says.

In fact, in time, the distinction between the network and what connects to it will disappear, says Manzalini, who is a senior manager at the Future Centre, part of Telecom Italia's strategy and innovation department in Turin [see his profile on p. 16].

BUILDING A COMMUNITY

Much about the new architecture has yet to be defined. That's why in May 2013 IEEE launched its Software Defined Networks Initiative, designed to explore how the technology will affect today's networks. The initiative has formed committees on education, certification services, publications, standards, and conferences, and it is establishing connections with IEEE activities in related areas such as cloud computing, the Internet of Things, and consumer electronics.

"We want to create a large technical community of experts in academia and industry across the globe to work collaboratively to face the new challenges," says IEEE Fellow Prosper Chemouil, chair of the SDN Conference Subcommittee. He is director of the Future Networks program at Orange Labs, in Paris.

NETWORK NUANCES

To comprehend how SDNs work, it's necessary to understand how traditional communications networks operate.

Each router and switch in a network is controlled at different layers so as to consistently address traffic transported as packets. Control planes decide how to route the traffic, which flows in the data plane, and where network applications are embedded. Much of the network's intelligence for how it deals with traffic is scattered among all the devices distributed along the way.

The development of IP networks mainly relied on the distribution of intelligence in various network elements, and it proved to be robust in providing end-to-end services. The need for a logically central intelligence and control becomes clearer, however, when it comes to serving many types of applications with different quality-of-service requirements in a customized manner, Manzalini says.

That is where SDNs can make a difference. They can consolidate the control plane so that a single logically centralized software program controls multiple hardware elements. The control plane operates the state of the network's data-plane elements (its routers, switches, and middleboxes) through well-defined APIs. It is this interface that enables applications to communicate with the infrastructure through an SDN controller, adds Chemouil.

"The network is configured and controlled through software, giving network providers more flexibility in how they use their resources," he says. "In this sense, SDN controllers might be logically centralized, depending on the requirements of the network architecture."

The future telecommunications network will look more like a distributed computational system, he continues. That means a network function could be executed either in the cloud or in the distributed telecommunications nodes.

"Software-defined networks are about creating very dynamic virtual networks out of a variety of aggregation nodes [routers with computing and storage capabilities], devices, and elements located at the edge of the network, down near the users," Chemouil says.

BLURRED LINES

The number of terminals, devices, and machines connected to telecommunications networks is growing exponentially. Fortunately, the principles of SDNs and virtualization are creating the conditions for reinventing network architectures to support the flexibility and dynamics of the growing number of advanced terminals and intelligent machines at the edge.

"The availability of open-source software and low-cost, high-performance IT hardware will allow service providers to install, program, and execute functions and services just like applications," Manzalini says. "To the networks and the clouds, platform-hooking terminals will look like a fluid virtual environment of services.

"The border between cloud computing and networking infrastructure will start to blur," he adds. "The border between the network and the terminals that are attached to the network will also disappear, because network functions could be executed in the cloud, in the network node, or even in terminals near the users."

VIRTUAL VISION

Network functions virtualization (NFV) is often paired with SDNs. The concept, which dates back to the 1960s, aims to use CPU virtualization and other cloud-computing technologies to migrate network functions from dedicated hardware to virtual machines running on general-purpose hardware. Virtualized network functions are appealing to network operators because they can be migrated and adapted to meet current demands and at the same time increase the utilization of network resources and decrease operating costs.

SDNs and NFV are mutually beneficial, but according to Manzalini, they do not depend on one another. For example, services can be developed in software and executed or emulated on logical resources without deploying an SDN, and vice versa. The combination can create an environment of virtual resources, interconnected by virtual links that are easily set up and torn down to serve multiple applications.

"Joining these two concepts can yield the most powerful network in terms of flexibility, programmability, and the ability to move virtual functions and resources while reducing costs and enabling new services," Manzalini says.

The IEEE SDN Initiative will test experimental applications of software, such as network functions, services, capabilities, and hardware (nodes and systems architectures), he says, enabling SDNs and NFV to perform and conform to standards.

"The initiative's work will accelerate SDN adoption by industry and help in creating new businesses," Manzalini says. "SDNs will provide opportunities not only for IEEE but also for the academic and industrial worlds to explore."

Software Already Defines Our Lives

But the impact of SDN will go beyond networking alone BY KATHY PRETZ

THE ADVENT OF software-defined networks (SDNs) and network functions virtualization (NFV) is going to affect just about every part of our lives, including driving, shopping, and health care. Advances are making cloud-computer networks and virtual IT platforms accessible to just about anyone on the so-called edge, where most of us hang out with our terminals: smartphones, tablets, and wearables. The boundaries have been blurred between terminals and networks and between networks and the cloud.

Embedded communications and processing are about putting everything about us in the cloud or in the fog (which extends cloud computing to the edge of the network). Soon there will be more software services and applications than ever before, experts say, leading to a plethora of intelligent machines. The machines will be able to sense, process, and exchange information, understand what's happening around them, and adapt to change.

"Advances in technology performance and decreasing costs of processing ultrabroadband connectivity are creating the conditions for reinventing network architectures so as to support flexibly and dynamically the burgeoning number of new advanced terminals and intelligent machines at the edge," says IEEE Member Antonio Manzalini, chair of the IEEE Software Defined Networks Initiative. "This will ultimately change the socioeconomic landscape; it's a technological tipping point that will alter the space-time of society."

That "software-enabled concept," as he refers to it, is being called "softwarization" or "IT-ization." SDNs and NFV will make telecommunications infrastructures more pervasive, flexible, and capable of supporting all those terminals out there, he says. Consider these examples of machines out on the edge that are part of softwarization:

- Self-driving vehicles, which are expected to be commercially available by the end of this decade. They could save lives by reducing traffic accidents.

- Unmanned aerial vehicles—drones—which are becoming commercially popular. Most are expected to be used in agriculture. For example, farmers could see patterns in their fields that indicate soil variation, irrigation problems, pest infestations, and changes to healthy plants. Delivery drones are anticipated as well.

- Robots, which are already in factories and hospitals and on farms. They can do the same physical work as people, but they can do it for 24 hours or more at a stretch, with minimal maintenance.

- Medical sensors and actuators, which can be embedded in clothing or as part of smartphone apps, along with wearable devices to monitor heart rate, calories burned, blood sugar, and cholesterol.

- Fitness apps and wearables, such as the Nike FuelBand, which track walking, jogging, dancing, and other activities. Apps can help plan healthy meals and monitor caloric intake. Some fitness and nutrition apps are able to share information via the cloud to monitor the user's health. Apple's new Health app and its iOS 8 operating system can present your information succinctly, because its HealthKit software tool allows its health and fitness apps to work together.

- Intelligent personal assistants, such as Apple's Siri and Microsoft's Cortana and robot servant Jibo, which help people with daily activities.

"Softwarization means that the threshold of investment for new players to enter the ICT [information and communications technology] market will dramatically decrease," Manzalini says, "leading to the launch of new businesses and new forms of cooperation and competition."

The changing roles and relationships among network service providers, content producers, consumer electronics manufacturers, and telecommunications vendors will call for new regulations, he says, particularly to protect personal information.

CHANGING LANDSCAPE

Softwarization is likely to make our lives easier, and it is also likely to affect the job market. Softwarization can help reshape the economy by optimizing processes. And forecasts predict more things will be manufactured locally—which, in turn, would reduce the need for long-distance transportation. That would mean less energy waste and pollution.

Looking further into the future, Manzalini says self-driving cars and trucks will reduce the need for human drivers. Smarter robots in agriculture and industry will reduce the risk of exposing people to harsh and hazardous environments, he adds. Drones will replace postal workers, messengers, and delivery drivers, he says. Telecommunications networks of the future will play a key strategic role, he predicts, becoming the "nervous system" of the digital society and economy.

"This transition will require new value chains and different kinds of jobs and workers," he says. "New skills will be needed. As technology races ahead, workers will have to be reallocated to tasks that computers and intelligent machines will never be able to carry out, such as designing and educating, and doing other work that requires creativity and social intelligence."

That's why the IEEE SDN Initiative is working on alerting educators, employers, politicians, and others to the enormous impact that softwarization is likely to have.

"Education will be very important in understanding the implications of the transition toward the digital society and digital economy, as well as identifying the new roles and skills required to deal with such a transition," Manzalini says.

THIS PAGE AND OPPOSITE PAGE: CARL DETORRES

IEEE QUICK GUIDE

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CAREERS

Five Skills for Managing Software-Defined Networks

What IT and network engineers will need to succeed BY KATHY PRETZ

IN TODAY'S NETWORKS, most management operations are carried out by people. But software-defined networks (SDNs) are going to change that by automating many processes to reduce human input and the mistakes that can be made. And with those changes, IT professionals will need new skills.

These people are going to be on the front lines where SDNs are designed, operated, and managed. They will also be implementing policies that increase performance and troubleshooting programs that go awry. According to Antonio Manzalini, chair of the IEEE Software Defined Networks Initiative, IT and network engineers will need to acquire a "systemic" mind-set aimed at integrating design and operations in data centers and telecommunications networks, as the border between the two domains blurs. These engineers will be in charge of enabling successful SDN deployment.

NEW TALENT

With the softwarization of telecommunications infrastructures [see p. 8], Manzalini says engineers will need the following five skills to develop new SDN tools, products, infrastructure, and applications:

1. The ability to incorporate know-how from the IT and network domains, which have grown independently of each other over the years but are now converging.

2. An understanding of industrial mathematics, a branch of applied mathematics. Those with this knowledge will be better able to understand technical issues, formulate precise and accurate mathematical models, and implement solutions using the latest computer techniques. An understanding of this field will help in developing systems by applying machine learning and cognitive algorithms, which are expected to lessen the complexity and dynamic nature of SDNs.

3. A mastery of software architecture and open-source software, which is needed to develop SDN tools and applications. It will also be helpful to understand software verification and validation processes, which ensure that software meets specifications and fulfills its intended purpose. Some engineers assume they'll need programming skills, but that's not necessarily so, because software applications for SDNs from third parties are already available.

4. A background in big-data analytics in order to understand how to handle the huge amounts of data expected from SDNs. Someone skilled in big-data analytics will not only be able to manage more data but also know the right questions to ask should problems arise. Such analytics will also help engineers make smart, data-driven decisions.

5. Expertise in cybersecurity, because security must be everywhere within SDNs. It needs to be built into the architecture and also must be delivered as a service to protect the availability, integrity, and privacy of connected resources and information.

"Education is very important, because the IT and networking communities are speaking different languages," Manzalini says. "Telecommunications engineers are the ones who developed and are executing the telecommunications metrics in place today. The IT people developed and are executing cloud computing, so there is a conflict between the two specialties, coming as they do from past architectures.

"We need to teach both of them to speak the same language."

Should Tech Companies Hire Hackers?

As more businesses rely on software-defined networks, the need to keep their systems secure becomes paramount. Google, Tesla Motors, and other companies have decided that rather than try to outsmart hackers, they will protect themselves by hiring them.

Shortly after hacker George Hotz dismantled the defenses of Google's open-source Chrome operating system in March, the company hired him to join its Project Zero team to detect security flaws in its software. And in August, Tesla announced it would hire 30 hackers to try to break into its all-electric Model S. The Tesla electronics security team would be the biggest in the auto industry. With so much of the company's vehicles dependent on software, Tesla wants the hackers to uncover any vulnerabilities.

Do you think companies should hire hackers to uncover security glitches, or should they leave it to their engineers?

Chime In...

Respond to this question by commenting online at http://theinstitute.ieee.org/opinions/question.

LEFT: SOYHAN ERIM/GETTY IMAGES; RIGHT: GETTY IMAGES

The Buzz About Big Data

In September, *The Institute* reported on the work of IEEE members to make sense of the world's growing mountains of data. It also reported on several big-data applications. Here are some readers' comments from our website about articles in that issue, which have been edited for space.

IMPROVING HEALTH CARE THROUGH DATA

We highlighted ways that health analytics could cut costs and improve care. Several readers were optimistic that big data could do so.

D. Holmes said, "It's about time that the medical field started using more innovative ways to help improve the quality of health care—especially preventative care. Gone should be the days where a huge portion of medicine is about treating symptoms and not actually curing patients' conditions or even preventing illnesses in the first place."

Maryam added, "The access to mountains of data and the powerful simulation tools and algorithms that enable us to get to answers quickly can only mean one thing: Providing better and less expensive health care worldwide."

SHOULD BIG DATA DETERMINE SALARIES?

To offer employees competitive pay, recruiters are turning to big-data platforms for help with setting salaries for workers with in-demand skills.

One reader had concerns about the practice: "Relying on compensation-information services enables companies to engage in wage fixing, or purposely putting a cap on salaries, without actually conspiring directly with other companies in the industry."

Craig Hartmann had a different take: "Companies are gathering data about what other companies believe to be a fair and reasonable wage to pay a person for his or her services based on experience, location, and skills. Companies do not want to offer much higher salaries than their competitors. That is not wage fixing, just good business."

WITH BIG DATA COMES BIG RESPONSIBILITY

In his column, IEEE President J. Roberto Boisson de Marca wrote about the collection and analysis of personal data.

Roger Graves is leery of the practice: "If a company analyzes my spending habits and decides that I am likely to buy cookies this Sunday, it may send me a coupon, but I am under no obligation to use the coupon or buy the cookies. However, if my health insurance company decides that my cookie-buying habits put me at greater risk of health problems, it may raise my medical insurance premiums, and I would have no option but to pay those premiums."

ASK THE EXPERTS

We invited readers to submit their questions about big data to IEEE experts in the field. A selection of questions and the experts' responses were published online on 1 October.

One reader asked, "Is big data merely a recent marketing term, or can it actually provide us with new information we couldn't get a few years ago?" IEEE Fellow Grady Brooch, chief scientist for software engineering at IBM Almaden Research Laboratory, in San Jose, Calif., said, "I worked with military and industrial groups in the 1980s and 1990s that collected large volumes of data. The difference now is that data is no longer used for these niche purposes alone and has instead become part of the mainstream—it's available to just about any industry."

Another reader inquired, "What is the difference between 'big data' and 'large amounts of data,' and where is the line drawn?" IEEE Fellow Manish Parashar, founding director of the Rutgers Discovery Informatics Institute, in Piscataway, N.J., responded, "Although increasing volumes, velocity, and variety are important dimensions of big data, even more important is the tremendous impact that the data can have on business, engineering, medicine, science, and society at large."

Join the conversation by visiting http://theinstitute.ieee.org. New articles and blog posts are added each week.

PRESIDENT'S COLUMN

IEEE, 2014 and Forward

WHEN YOU ARE president, you get only four of these columns during your term to write about topics you're interested in. In the past, I have shared my thoughts on the emerging technologies of the day, the role IEEE is playing or could play there, and the issues that all of us, as engineers, must focus on. But what of IEEE itself?

We are more than just conferences, or just publications, or just members and volunteers. We are a vibrant community, growing every year, producing more diverse and insightful work than any similar organization in the world. We are all this, but we are much more.

In the past year, we have seen our Women in Engineering affinity group hold its inaugural International Leadership Conference. It was a resounding success, and it should serve as inspiration for similar future endeavors throughout IEEE. Another important effort under way is to organize our humanitarian technology activities to guarantee that IEEE will increase its impact in this most important area.

Likewise, we have seen tremendous growth in our program Engineering Projects in Community Service (EPICS) in IEEE. In this outreach program, section volunteers mentor IEEE student and graduate student members as they work with high school students on engineering projects that can help their communities. EPICS is affecting young technologists the world over and changing the lives of individuals and communities.

And even more exciting possibilities arose this year. Chief among them was a demonstration model of IEEE's Professional Productivity and Collaboration Tools (PPCT), an online community where IEEE members and other technology professionals in similar fields can connect, collaborate, create, and save time managing research collections and discover new ideas or career opportunities. PPCT will be a significant step forward in addressing a long-term need of the IEEE membership. It has the potential to be a transformative agent of change within our global community.

Another promising development for IEEE is the evolution of its role in continuing professional education. Throughout 2014, we dedicated time, energy, and expertise to this important field. As technology evolves exponentially and R&D, innovation, and production become increasingly global, technology professionals must continue to learn throughout their careers.

It is imperative that IEEE be one of the driving forces in professional education. We must take advantage of modern online platforms and our unique worldwide volunteer corps, which can provide a local perspective on the skills needed by local businesses almost anywhere on our planet.

IEEE must still focus on answering several questions, however:

- How do we enhance the membership experience and provide content and value to those who choose to be part of the IEEE community?
- Is our current infrastructure of regions, councils, sections, and subsections the best one and if it's not, what should a new structure look like?
- What is the best way to expand our preuniversity offerings to encourage more young people to pursue science, engineering, and technology careers?
- How can IEEE best improve its engagement with industry and with the countless numbers of professionals working within industry?
- How can IEEE change its business model to adapt to the new reality that people expect raw information for free but are willing to pay for value-added services that result in knowledge that helps solve the problems they are working on?
- What will be the role of professional organizations such as IEEE in a future where people increasingly use social media platforms to satisfy their need for networking and professional information exchange? Finding an answer to this is already a challenge, and it will become more so with the evolution of social media tools.
- How can IEEE keep its volunteers motivated and engaged so that it can continue to be the leading source of trustworthy and unbiased information, which is essential to its success in an increasingly cyberfocused society?

This is not intended to be an exhaustive list of the challenges facing IEEE; it is merely a brief list of what must be paramount in our thinking in the coming years.

I do know one thing about these questions. No one individual among us, including myself, has all the answers to all of them. But together, as the global IEEE community, we can—and will—answer these questions.

All the programs I mentioned are the result of dozens, hundreds, even thousands of individuals working within the world of IEEE. A future of promise and possibility lies ahead. We in IEEE will build that future as we have been doing since 1884—together.

I thank you all for an extraordinary year and would like to hear your thoughts on IEEE's future. Please share them with me at president@ieee.org.

J. Roberto Boisson de Marca
IEEE President and CEO

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RON NEWKIRK

Sources of Information on SDNs

IEEE offers technical articles and online courses BY **MONICA ROZENFELD**

WITH THE LAUNCH of the IEEE Software Defined Networks Initiative, resources are being developed to get members up to speed on SDN technology. Here's what's available.

WEB PORTAL

A good place to start is the SDN Web portal (http://sdn.ieee.org), which carries news of the latest IEEE activities, research articles, and upcoming conferences and events.

EDUCATION

On the Web portal, under the Education tab, is a library of online tutorials and courses. There you can watch a video on, say, how SDNs will shape networking or sit through an introductory tutorial on OpenFlow—the first standard communications interface defined between the control and forwarding layers of the SDN architecture. You can also take an online course taught by professors at Washington University, in St. Louis, and Georgia Tech that explains the ins and outs of SDNs and network functions virtualization.

PUBLICATIONS

The IEEE Communications Society ran a special issue in August on SDNs and virtualization trends in its online publication, *ComSoc Technology News*. The issue examined how the shift to SDNs could reinvent network computing platforms and network architectures. Included in the issue was "Are We Ready for SDN? Implementation Challenges for Software-Defined Networks."

IEEE Transactions on Network and Service Management is to be introduced in March with a special issue on efficient SDN management and network functions virtualization.

TECHNICAL ARTICLES

The IEEE Xplore Digital Library has several research articles on SDNs. The *IBM Journal of Research and Development* published "Software-Defined Networking to Support the Software-Defined Environment" in May. It covered several technologies used for SDNs and the benefits they offer to service providers and end users. The article also presents IBM's vision for the technology, describing how it will work to virtualize the underlying physical network infrastructure and automate resource provisioning.

Other papers include "Softwarization of Future Networks and Services: Programmable Enabled Networks as Next-Generation Software-Defined Networks," published in the 2013 IEEE SDN for Future Networks and Services conference proceedings. Another paper, "Software-Defined Networking (SDN): A Reference Architecture and Open APIs," ran in the 2012 International Conference on ICT Convergence proceedings and covered application programming interfaces (APIs) and architecture for open networking environments.

IEEE

BUILDING A COMMUNITY

From the Web portal, you can also join the IEEE Software Defined Networks Technical Community, a group that helps promote IEEE's role in advancing SDN technology by furthering research, organizing conferences, testing application platforms, and more.

SOCIAL NETWORKS

The SDN initiative has its own Facebook group (http://facebook.com/IEEESDN) where the latest developments can be shared and discussed. To follow the activities of the initiative's working group, visit its blog (http://ieee-sdn.blogspot.com). Written by the group's members, topics include the mind-set and skills required to work in the field, an estimate of how big the market is for SDNs, and how to adapt to an SDN environment.

IEEE.tv offers videos on the topic, including one from IEEE Senior Member Roberto Saracco, chair of the Future Directions Committee, who presents his view on the benefits to be gained by switching to SDN technology.

Working Toward the Next Generation of Networks

IEEE standards projects aim to advance SDNs

BY **MONICA ROZENFELD**

THE IEEE Communications Society met in April with experts from academia and seven leading communications companies to discuss standardization opportunities for software-defined networks. The meeting resulted in the establishment of two research groups and two study groups, which are expected to lead to IEEE Standards Association working groups.

Two related IEEE projects are already under way: P1903 and P802.1CF.

GROUP EFFORT

The Research Group on Software Defined and Virtualized Wireless Access is working on interoperability issues, ways to extend software-defined network technology to mobile devices, the use of SDNs to control and program network resources, and methods for extracting and managing information necessary for wireless network controllers.

The Research Group on Structured Abstractions is identifying and formulating standardization efforts. The group is working on creating the object structure of the common data layer that the integration framework components use for application message processing. This is needed for standardizing network interfaces and descriptors.

The Study Group on Service Virtualization hopes to leverage the existing body of work on next-generation service overlay networks. The goal is to provide new capabilities by merging and exploiting real-time service, terminal, and network information for each network. The group also plans to define service-specific functions for virtualization and softwarization.

The Study Group on Security, Reliability, and Performance for Software-Defined and Virtualized Ecosystems is working to identify critical SDN framework details including service virtualization priority classes; reliability, security, and performance use cases and applications; and key performance indicators.

RELATED PROJECTS

The following standards are under development by IEEE working groups.

IEEE P1903

"Next Generation Service Overlay Networks (NGSON)" is an IEEE Communications Society–sponsored effort to standardize a service ecosystem for the benefit of network operators, service and content providers, and end users. Protocols are being developed for service creation, content delivery, and self-organizing management.

A reference framework of IP-based service overlay networks for collaborative and customer-centric service delivery has been standardized already. It includes context-aware, dynamically adaptive, and self-organizing network capabilities such as advanced routing and forwarding schemes. The goals are to accelerate the proliferation of SDN services and applications and to offer a more efficient way of providing them through a service-architecture ecosystem of one-stop shopping for service-specific challenges.

IEEE P802.1CF

"Open Mobile Network Interface for Omni-Range Area Networks (OmniRAN)" is focused on network reference models and functional descriptions based on the family of IEEE 802 standards, which deal with local and metropolitan area networks. The project encompasses work on functional entities and reference points along with behavioral and functional descriptions of communications involved in SDNs.

For more information, visit http://standards.ieee.org.

Conferences: February–May 2015

IEEE events cover topics related to software-defined networks

IEEE Conference on Network Softwarization

LONDON; 13–17 APRIL

TOPICS: Architectures of software-defined networks (SDNs), programming interfaces and languages, debugging tools, network functions virtualization (NFV), network and service management, SDN security and quality of service, life cycle management, energy-efficient and software-defined infrastructures, and SDN support for big-data applications.

SPONSORS: IEEE Communications, Computer, Consumer Electronics, and Signal Processing societies and IEEE Future Directions Committee
VISIT: http://sites.ieee.org/netsoft

XAVIER ARNAU/ISTOCKPHOTO

IEEE International Conference on Intelligence in Next-Generation Networks

PARIS; 17–19 FEBRUARY

TOPICS: Paradigms for communications architectures, content-centric networks, context-based communications, requirements for NFV and cloud technologies, service chaining, virtual network functions as a service, energy efficiency and management, and the Internet of Things.
SPONSOR: IEEE Communications Society
VISIT: http://www.icin.co.uk

Workshop on Software-Defined Networking and Network Functions Virtualization for Flexible Network Management

COTTBUS, GERMANY; 12 MARCH

TOPICS: Held in conjunction with the International Conference on Networked Systems (9–13 March), the workshop will cover SDN and NFV architectures and applications, network monitoring and quality, reliability of virtualized network functions, SDN-based deployment and management, SDN and NFV security, and theoretical foundations of SDN and NFV networks.
SPONSOR: IEEE
VISIT: https://www.netsys2015.com/workshops-tutorials/sdnflex

IEEE Conference on Computer Communications

HONG KONG; 26 APRIL–1 MAY

TOPICS: SDN applications, computer and data communications networks, cognitive radio networks, information-centric networking, network science and virtualization, overlay and peer-to-peer networks, Web applications, and content distribution.
SPONSOR: IEEE Communications Society
VISIT: http://infocom2015.ieee-infocom.org

IFIP/IEEE International Symposium on Integrated Network Management

OTTAWA; 11–15 MAY

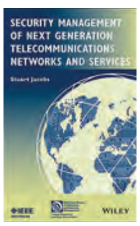
TOPICS: Network and service management with respect to items like SDN, the Internet of Things, content distribution networks, data centers, storage area networks, cloud computing services, policy-based management, programmable networks, NFV, service chaining, operations and business support systems, and data analytics and mining.
SPONSORS: International Federation for Information Processing (IFIP), IEEE Communications Society
VISIT: http://im2015.ieee-im.org

E-Books on Networking Systems

HERE'S A SAMPLE of IEEE e-books that focus on a variety of networks. To view the books, log in to the IEEE Xplore Digital Library and click on "Books & eBooks" in the left-hand navigation menu. You can then browse or search by title and download a PDF of an excerpt or of selected chapters. To order books, visit http://www.wiley.com.

Security Management of Next Generation Telecommunications Networks and Services

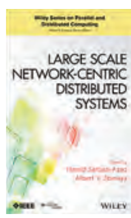
BY STUART JACOBS (2014)



A guide for improving the security of enterprise and service-provider networks, including virtualized networks. The book reviews key security concepts, such as authentication, threats, and vulnerabilities. It also details effective approaches to encryption, and it covers the importance of governance in analyzing security standards and management frameworks.

Large Scale Network-Centric Distributed Systems

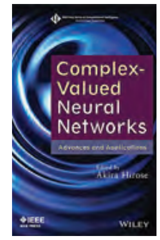
EDITED BY HAMID SARBAZI-AZAD AND ALBERT Y. ZOMAYA (2014)



An in-depth reference that covers design and performance issues related to wired and wireless networks. Chapters include information on grid and cloud computing, systems-on-a-chip, and middleware support.

Complex-Valued Neural Networks: Advances and Applications

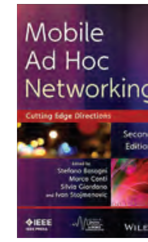
EDITED BY AKIRA HIROSE (2013)



A comprehensive resource that presents recent advances. Included are a variety of applications in which signals are analyzed and processed, such as communications and image-processing systems and brain-computer interfaces.

Mobile Ad Hoc Networking: Cutting Edge Directions, Second Edition

EDITED BY STEFANO BASAGNI ET AL. (2013)



A look at recent research and developments. The authors review networks that have successfully adopted the multihop ad hoc method and explore how these networks have penetrated the mass market and sparked breakthrough research. The book offers tools for learning about actuator, robot, and sensor networking.

Global Networks: Engineering, Operations, and Design

BY G. KEITH CAMBRON (2013)

A compendium of trends that examines ways to develop, introduce, and manage telecommunications technologies. It includes how to design networks that are fault-tolerant and global in scope and how to identify best practices.

WILEY-IEEE PRESS (5)

PEOPLE

Antonio Manzalini: Innovating Networks

Advancing the softwarization of networks for a digital society

BY **PRACHI PATEL**

BY THE END of this decade, billions of new terminals and devices, including smartphones, tablets, and robots, will have come out on the market, each containing embedded communications and dozens, if not hundreds, of sensors and actuators. Telecommunications infrastructure will play a key role, becoming the nervous system of a digital society and economy by supporting this tremendous number of new terminals and devices.

To keep up, many in the IT and telecom communities say a new architectural model—software-defined networks (SDNs) together with network functions virtualization (NFV)—will be needed. By decoupling hardware from software, SDN technology is expected to make networks simpler to manage, more flexible, quicker to build and deploy, and more cost-effective. Virtualization, on the other hand, will allow cost optimizations.

IEEE Member Antonio Manzalini, chair of the IEEE Software Defined Networks Initiative, wants to make sure that the sweeping transition will create new socioeconomic opportunities. Imagine, for example, the business ecosystems that will be created by the synergies of SDN and cloud robotics: new mobile robots—smarter and controlled through the network—will be exploited for industrial and agricultural tasks, easing the burden on workers while optimizing the processes. He is helping to make that transition a success through experimental activities, standardization, and explaining and promoting SDN technology through the media, workshops, publications, and conferences. The first-ever IEEE Conference on Network Softwarization is scheduled for 13 to 17 April in London [see p. 14].

"The network of the future will seamlessly interconnect a tremendous number of terminals, devices, machines, and smart objects at the edge—where the users are—with the enormous processing power available in the cloud," Manzalini says. "Cloud computing, SDNs, and NFV are different facets of the same worldwide industry transformation toward the 'IT-ization' of any process."

DEFINING FUTURE NETWORKS

Manzalini has been working for Telecom Italia for almost 25 years. Since 2007, he has been a senior manager at the Future Centre in Turin, Italy, part of the telecommunications giant's strategy and innovation department. He is in charge of investigating SDN, NFV, and 5G technologies, enabling innovative service scenarios, and foreseeing their potential socioeconomic impact. In addition to hands-on research and innovation, he works with global industries and academic partners to define requirements and standards for future telecommunications infrastructure.

Current telecom networks can be thought of as interconnected complexes of equipment such as transport nodes, routers, switches, and middleboxes that shuttle data traffic from one node to the next across the network. The equipment is mostly based on specialized hardware and closed software.

SDNs separate the hardware (which forwards the data packets) from the software (which is in charge of controlling the routers). One main novelty is the fact that software is then executed not necessarily in the equipment but potentially in the cloud or on distributed servers. Another key aspect of SDNs is a wide number of abstractions and application programmable interfaces to program the functions and services of network resources.

"Nevertheless, SDNs should not be seen as the next generation of switching and networking," Manzalini says. Simply put, through SDNs and NFV, all the network functions provided today by middleboxes could be virtualized and executed in the cloud and in various locations in the network as required. That gives administrators cost savings, flexible control, and a big-picture view of the entire network so they can quickly create and deploy new services.

Manzalini says the integration of the two should make it easier for new operators to enter the market. "SDNs and NFV can be seen as expressions of a systemic trend, called IT-ization or 'softwarization,'" Manzalini says [see p. 8]. "This trend is enabled by IT technoeconomic drivers, and it will produce cost reductions via automation and optimization of processes everywhere."

ADDRESSING NEEDS

At Telecom Italia's Future Centre, Manzalini investigates the most novel applications of SDN and NFV technologies and monitors their progress. Under his guidance, and in partnership with other international players, researchers are carrying out theoretical analyses, computer simulations, and experimental validations of the new network models.

Technology innovation is just one part of Manzalini's job. He is also in charge of understanding SDN's socioeconomic impact—for example, addressing the technologies' business sustainability and analyzing their effect on regulations.

Manzalini grew up in Turin, devouring science fiction books and movies, fascinated by their depiction of technology. He says he knew he wanted to become an engineer when he was 12 years old.

He earned a master's degree in electronic engineering from the Politecnico of Turin. After graduating, he considered jobs at the European Space Agency, IBM, and a former Telecom Italia research center. The job at Telecom Italia was closer to his career dreams at the time—which, he says, were "to investigate advanced telecommunications technologies and the way they could help to progress and to solve the grand challenges of humanity."

He joined Telecom Italia in 1990, researching technologies and architectures for optical networks. Over the years, he led several international projects funded by the European Commission and was involved in a number of standardization activities. The move to the Future Centre in 2007 was a logical next step, he says.

Manzalini is also busy pursuing another passion: He is investigating the complexity of swarm intelligence in nature, in phenomena such as flocks of birds, ant colonies, and clusters of particles—a subject that has interested him for a decade. Such collective behavior has networking principles in common with quantum particles, neurons in the brain, and humans in society, he notes. "Nature is ahead of us: We should develop our new technologies by learning from nature."

ELISABETTA RAMONDETTI

Part-time Passions

Andrew Dawkins

Making statements

FOR TWO YEARS, IEEE Member Andrew Dawkins has been creating pasteups, or paper cutouts of illustrations that can include images, words, and designs pasted on public walls. They are meant to be attention-grabbing if not controversial.

The art form is a natural for Dawkins, 26. From an early age he has expressed himself through drawings. "Instead of writing down how I felt about things, it was much easier to draw them out in a visual diary," he says. "Eventually, I began adding phrases to the images."

Dawkins's first few pasteups, which depicted cannibalism, might have made some people uneasy. But he has since shifted to images that are, as he says, "cool, carefree, and less pretentious."

One of his latest works, for example, revolves around Big Red and Little Blue, two humanlike characters he created that have no facial features. Dawkins says he wants people to enjoy spotting the characters: "It's nice if I'm strolling around and I see people stop to take a closer look or just go, 'There's another one!'"

Dawkins, who earned a mechatronic engineering degree in 2009 from Curtin University in Bentley, Australia, went to work upon graduation in nearby Fremantle as a design engineer at Maritime Engineers, a consulting firm that provides naval architecture and design services. There he worked on a ship's anchor that can be released remotely in an emergency. He recently moved to Melbourne and applied to a master's degree program in sustainable energy technologies at RMIT University.

He has long admired street art. Growing up in a northern suburb of Perth, in Western Australia, he admired the huge murals painted on underpasses near his home. Then, traveling alone in Europe in 2011, he was captivated by the street art in and around Berlin and was inspired to look into pasteups.

"You can put so much work and thought into creating them, but the key is to place them in the right surroundings that will add to the art and make people stop and think," he says. "I really enjoy doing pasteups that interact with their settings." For one of his recent efforts, he placed his Little Blue character hanging off the edge of an exhaust vent panel on a building while Big Red stood on top of it, as if looking for Blue.

Back from Berlin, he moved to an artsy region outside Perth, where an abandoned power station near a beach had become the local street artists' mecca. Its walls were covered with murals and spray-painted pieces—some, particularly in the United States, might call it graffiti—by artists who were practicing new techniques.

To make his pasteups, Dawkins first designs his illustrations using software and then prints them out. He has experimented with paper of different thicknesses and adhesives including store-bought wallpaper paste and home-brewed wheat pastes. Some pastes degrade quickly, crinkle the paper too much, or are too thick to fill wall crevices or hold the paper fast to a wall. Dawkins currently favors butcher paper, which is relatively thin, and a homemade paste made of flour, sugar, and water.

"I get geeky trying to find the best combination," he says. "The way you might approach an engineering problem is fundamentally similar. You have to concentrate on one thing, think about it, plan it, and execute it."

— Prachi Patel

LEFT: STEPHEN JAHNS; RIGHT: DONNA BALLARD

John Ballard

Rocket man

IEEE MEMBER John Ballard, 58, calls himself a classic "born-again rocketeer." The story of how he got into what's known as high-power rocketry is a common one, he says: Parent helps kid build a rocket; kid thinks rockets are unbelievable fun; kid becomes a teenager. "It's just a slippery slope from there," the electrical engineer says with a laugh.

Although Ballard is self-taught, he shared his love of rocketry with his kids some 15 years ago when he helped them fashion rockets from toilet-paper tubes and cereal boxes. The children would shoot them into the air using off-the-shelf rocket motors. For Ballard, at least, his hobby has since evolved to high-power rocketry. Instead of plain old model rockets, he relies on higher-impulse-range motors. His rocket is powered by four kilograms of fuel. And hobbyists like him are required to be certified by an organization such as the Tripoli Rocketry Association, in Bellevue, Neb., to comply with safety regulations.

Three levels of certification determine the complexity of the rockets a hobbyist may launch. Ballard received the highest level—Level 3—five years ago. Not only are his rockets allowed to fly highest, they have onboard electronics that measure parameters such as acceleration, peak altitude, and velocity and can deploy a parachute to land them safely on the ground.

Rather than using commercial components, Ballard designs his own rockets and makes them from scratch. He typically tweaks and builds on his past projects or works off others' designs. For his latest endeavor, a 4.5-meter-long, 114-millimeter-wide rocket he named Scrapyard Cinderella, Ballard repurposed scrap material including petroleum fiberglass piping and plastic pieces bought from local businesses as well as flattened aluminum beer cans. The rocket weighed about 17 kilograms at liftoff.

He spends about US $4,000 a year designing and building electronics-laden rockets that can soar from 1,500 to 4,500 meters into the sky. He can fire them once a month, along with several dozen members of his local rocketry club, from the Black Rock Desert, about a 2-hour drive from his home in Sparks, Nev. The flights are conducted under a Federal Aviation Administration waiver that temporarily grants airspace to club members.

As a production engineer for Sierra Nevada Corp., a defense electronics contractor in Sparks, Ballard builds and tests secure wireless computing and communications devices. The technical aspects of high-power rocketry attract him as an engineer, he says. For each machine he builds, for example, he has to calculate whether the case for the rocket's motor—which he makes himself—will be able to withstand the pressure of the propellant. He uses on-paper calculations involving solid finite-element modeling.

"Rocketry is multidisciplinary," he says. "It exposes you to aerodynamics, machining, materials, mechanics, and thermodynamics. You must learn enough about all of these different areas to meet your goal."

His garage has become a workshop dedicated to building rockets. The time he spends there depends on the season, he says. Winters, he can tinker with the rockets for hours, two or three evenings a week. Summers are mainly for outdoor tests and launches. He doesn't really know how many hours he devotes to rocketry. "It's a passion," he says. "I'm afraid to know how much time I spend on it." *—P.P.*

In Memoriam

IEEE mourns the loss of the following volunteers who died this year

Thelma Estrin

FORMER IEEE EXECUTIVE VICE PRESIDENT
Member Grade: **LIFE FELLOW**
Age: **89**; *Died:* **15 FEBRUARY**

Estrin, who served as IEEE executive vice president in 1982 (a title no longer used), was the first woman to be elected to the IEEE Board of Directors.

She began her career in 1941 as an engineering assistant at Stevens Institute of Technology, in Hoboken, N.J., and next worked for two years at the Radio Receptor Co., in New York City. She returned to school and went on to earn bachelor's, master's, and doctoral degrees in electrical engineering at the University of Wisconsin–Madison, in 1948, 1949, and 1951.

She became an engineering researcher in the electroencephalography (EEG) department of the Neurological Institute at Columbia Presbyterian Hospital, in New York City, in 1951. An electroencephalogram records brain activity through electrodes along the scalp.

Three years later she and her husband, Gerald, accepted positions at the Weizmann Institute of Science, in Rehovot, Israel. They worked on the Weizac—the first large-scale electronic computer outside the United States and Western Europe. It was named an IEEE Milestone in 2006.

The couple moved to California in 1956, and Estrin taught engineering at Los Angeles Valley College. She left in 1960 to join the Brain Research Institute at the University of California, Los Angeles. Ten years later she was named director of the BRI's data processing laboratory, where she provided computing support for research projects and helped dozens of researchers make use of BRI computers.

She did pioneering work in medical informatics and the application of computers to medical research and treatment, and she organized events for UCLA faculty and students focusing on the issues and concerns of women in science.

In 1982 and 1983 Estrin served as director of the National Science Foundation's division of electrical, computing, and systems engineering. She was named professor emeritus at UCLA in 1991.

Estrin served as vice president of the IEEE Engineering in Medicine and Biology Society and belonged to the IEEE Computer Society. A fellow of the American Academy of Arts and Sciences, the American Institute for Medical and Biological Engineering, and the Society of Women Engineers, she was named an IEEE Fellow in 1977 for "contributions to the design and application of computer systems for neurophysiological and brain research." In 1999 she was inducted into the Women in Technology International Hall of Fame.

Estrin was in a family of IEEE Fellows. Her husband, who died in 2012, was elevated to Fellow in 1968. Her daughter, Deborah, a computer science professor at Cornell Tech, in New York City, was elevated in 2004.

Richard "Dick" Riddle

FORMER DIRECTOR, IEEE REGION 3
Member Grade: **LIFE SENIOR MEMBER**
Age: **83**; *Died:* **29 JULY**

Riddle was director of IEEE Region 3 (Southeastern United States) in 2000 and 2001. He also served as chair of the IEEE Winston-Salem (N.C.) Section.

He served in both the U.S. Army and Navy, specializing in air defense radar as well as antiaircraft and high-altitude guided missile systems, and he was an instructor at the White Sands Missile Range, in New Mexico.

After his service in the military, he joined Remington Rand, where he worked on Univac computers. In 1961 he left for Western Electric in Winston-Salem, where he helped develop electronic systems along with telephone hardware and software. He left there in 1989 to form Riddle Associates, a management and operations consulting firm.

Riddle was a lifelong student. He attended Wake Forest College, in Winston-Salem; Mars Hill University, in North Carolina; Texas Western College (now the University of Texas at El Paso); the University of Houston; and New Mexico State University, in Las Cruces.

Eugene I. Gordon

FOUNDER, IEEE QUANTUM ELECTRONICS COUNCIL
Member Grade: **LIFE FELLOW**
Age: **84**; *Died:* **15 SEPTEMBER**

Gordon was founder and first chair of the IEEE Quantum Electronics Council, which became the IEEE Photonics Society.

He spent his entire career at Bell Telephone Laboratories, in Murray Hill, N.J., where he worked on microwave traveling-wave tubes, lasers, and image and display devices. In 1970 he began consulting for the U.S. Department of Defense's advisory group on electron devices. He retired in 1983 as director of Bell's Lightwave Devices Laboratory.

Gordon helped form the IEEE Quantum Electronics Council in 1965. The council became the IEEE Quantum Electronics and Applications Society in 1977 and then in 1985 changed its name to the IEEE Lasers and Electro-Optics Society. It was renamed the IEEE Photonics Society in 2009. He cofounded *IEEE Electron Device Letters* and the *IEEE Journal of Quantum Electronics*.

He was elevated to IEEE Fellow in 1968 "for scientific contributions in the fields of electro-optics and quantum electronics," and he received the 1984 IEEE Edison Medal for "a singular career of invention, development, and leadership in electron devices."

Gordon earned a bachelor's degree in physics in 1952 from the City College of New York and received a Ph.D. in physics in 1957 from MIT.

FROM LEFT: WAYNE STATE UNIVERSITY; IEEE; IEEE

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For a career of meritorious achievement in electrical science, electrical engineering, or the electrical arts.
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For outstanding accomplishments in the application of technology in the fields of interest of IEEE that improve the environment and/or public safety.
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IEEE Founders Medal
For outstanding contributions in the leadership, planning, and administration of affairs of great value to the electrical and electronics engineering profession.
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For exceptional contributions to information sciences, systems, and technology.
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For outstanding contributions and/or innovations in engineering within the fields of medicine, biology, and healthcare technology.
SPONSOR: IEEE Engineering in Medicine and Biology Society

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For outstanding achievements in signal processing.
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IEEE/RSE Wolfson James Clerk Maxwell Award
For groundbreaking contributions that have had an exceptional impact on the development of electronics and electrical engineering or related fields.
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