Convergence Through the Cloud-to-Thing Consortium

By Tom Coughlin

At the 2017 IEEE International Conference on Consumer Electronics, the IEEE Technical Activities Board Future Directions Committee held its third special session focused on important cross-society trends in the future of technology. The 2017 session dealt with aspects of cloud computing, fog computing, and the Internet of Things (IoT). It included speakers from many IEEE Societies talking about trends from standards to storage, from data centers to the edge. This article includes information about this informative session and the participants.

Pushing computing, control, data storage, and processing into the cloud has been a trend during the past decade. However, the cloud alone is encountering growing limitations in meeting the many new requirements of the emerging IoT, such as reaching stringent latency specifications, supporting the vast number and variety of resource-constrained devices, overcoming the bandwidth and cost constraints for long-haul communications, dealing with ever-growing types and quantities of big data, and addressing many new IoT security challenges that cannot be adequately addressed by the existing security paradigms.

To fill the technology gaps, the cloud needs to descend to the network edge and sometimes diffuse onto end-user devices, which forms the fog. Fog computing distributes computing, storage, control, and smart networking services closer to the end users, including consumers. Instead of concentrating data and computation in a small number of large clouds, fog computing envisions many fog systems deployed physically or logically close to the end users or where computing and intelligent networking can best meet user needs.

Fog computing presents a new architectural vision where distributed edge and user devices collaborate with each other and with the cloud to carry out computing, control, smart networking, and data-storage tasks. Fog computing is seeing rapidly increasing applications in, and demands from, many industries, from manufacturing to smart cities to connected transportation to smart grids to e-health to oil and gas. The fog will serve as a platform for fifth generation (5G), IoT, and big-data analytics as well as other emerging disruptive communications and networking paradigms. For example, big-data analytics may benefit from dynamically distributing processing across the cloud-to-thing continuum (e.g., the continuum from set-top boxes and 5G smartphones to networks to servers in distant data centers) rather than just in the cloud.

On the journey to realizing fog computing, many new challenges will be encountered. For example, what fog computing architectures make the most sense? How will fog computing influence networking? How should the fog interact with the cloud? How should we compose, deploy, and manage distributed fog services and applications? How do we enable highly scalable and manageable fog networks and systems? How must we secure fog computing and networking systems and services? And how can we enable end users, such as consumers, to control their fog services?

Addressing these challenges necessitates rethinking of the end-to-end network and computing architectures. The information and communication technology industries, including chipmakers, networking companies, and software companies, have begun to devote significant efforts to develop fog computing technologies. A global industry–academia consortium—the OpenFog Consortium—has been launched with participation from major industry movers to accelerate market adoption of fog computing and to develop an open fog architecture.

The many profound research challenges in fog computing and networking are also drawing a booming interest in academia. In the special session panel, experts from industry and academia discussed their visions for 1) fog computing, communications, storage, and control, and 2) the challenges on the road ahead to making fog practical as an enabling architecture for applications such as IoT, 5G, and big data. The session chairs were Douglas N. Zuckerman and Kathy Grise.

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DOUGLAS N. ZUCKERMAN


Douglas N. Zuckerman

An active volunteer for more than 30 years, Douglas N. Zuckerman is a past IEEE Division III (Communications Technology) director, 2008–2009 president of the IEEE Communications Society, and previously held leadership positions in conferences, publications, and membership development. He earned his B.S., M.S., and Eng.Sc.D. degrees from Columbia University, New York. His professional experience, mainly at Bell Labs in Murray Hill, New Jersey, and Telcordia Technologies in Piscataway, New Jersey, spans the operations, management, and engineering of emerging communications technologies, networks, and applications.

His work heavily influenced early standards for management of telecommunications networks. Presently semiretired, Zuckerman is still active in standards as a representative to the OpenFog Consortium as a board member. He is also a consulting employee for Vencore Labs, Basking Ridge, New Jersey. He currently serves on the IEEE Communications Society's Board of Governors and the IEEE Future Directions Committee. He is an IEEE Life Fellow.

KATHY GRISE


Kathy Grise

Kathy Grise is senior program director of the IEEE Future Directions Committee; supports new technology initiatives; is the IEEE staff program director for the Big Data Initiative, Smart Materials Initiative, and the IEEE Technology Navigator; and manages the digital presence team for the committee. Prior to joining IEEE staff, Grise held numerous positions at the International Business Machines (IBM) Corporation, Armonk, New York, and most recently was a senior engineering manager for process design kit enablement in the IBM Semiconductor Research and Development Center. She led the overall information technology infrastructure implementation and software development in support of semiconductor-device-modeling verification, packaging, and delivery; device measurement and characterization data collection and management; and automation for device-modeling engineers. She is a graduate of Washington and Jefferson College. She is an IEEE Senior Member.

MUNG CHIANG

WHY FOG IS A NECESSITY


Mung Chiang

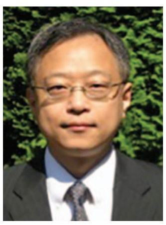
Is fog essential to the IoT, 5G, and embedded artificial intelligence (AI)? We explored four dimensions of unique advantages offered by fog: cognition, efficiency, agility, and latency, using examples from recent research from Princeton EDGE Lab, New Jersey.

Mung Chiang is the Arthur LeGrand Doty professor of electrical engineering at Princeton University. His research on networking received the 2013 Alan T. Waterman Award, the highest honor for young U.S. scientists and engineers. His textbook, *Networks: Friends, Money and Bytes,* and online course has reached 250,000 students since 2012.

He founded the Princeton EDGE Lab in 2009, which bridges the theory–practice gap in edge networking research by spanning from proofs to prototypes. He cofounded a few startups in mobile, IoT, and big-data areas and cofounded the OpenFog Consortium. He is the director of the Keller Center for Innovations in Engineering Education at Princeton University and the inaugural chair of the Princeton Entrepreneurship Council.

TAO ZHANG

ROLE OF FOG COMPUTING


Tao Zhang

Moving computing, control, and storage into the cloud has been a key trend in the past decade. However, the cloud alone is encountering growing limitations in supporting many new systems and applications, such as the IoT, 5G wireless systems, distributed data analytics, embedded AI, and more. Addressing the growing need for distributed computing requires a new paradigm—fog, which can dynamically distribute computing, storage, communication, and control services closer to the users, to the network edge, or anywhere along the cloud-to-thing continuum that can best meet user requirements.

Many new challenges arise in enabling fog computing and services, creating a fertile ground for innovation. What fog architectures make the most sense? How should fog interact with the cloud? How should we enable scalable, manageable, and reliable distributed fog systems and services? How should we secure such fog systems and services? The list continues.

Addressing these challenges necessitates rethinking of end-to-end computing, networking, and control architectures. In this talk, Tao Zhang discussed what fog is, how it complements and differs from other related technologies and initiatives, how it can help address some critical challenges we face, and what the global industry–academia consortium—the OpenFog Consortium—is doing to accelerate fog development and adoption.

Tao Zhang joined Cisco, San Jose, California, in 2012 as the chief scientist for smart connected vehicles and also leads the creation of strategies, technology, and ecosystems for IoT and fog computing. Prior to Cisco, he was chief scientist and director of vehicular networking and director of mobile networks at Telcordia Technologies (formerly Bell Communications Research or Bellcore), Piscataway, New Jersey. For more than 25 years, he has been in various technical and executive positions, directing research and product development in areas including vehicular networks, all–Internet Protocol cellular networks (third generation/fourth generation), and fiber-optic networks.

Zhang cofounded and is a board director for the OpenFog Consortium. He is the chief information officer and a board governor of the IEEE Communications Society. He cofounded and was a founding board director for the Connected Vehicle Trade Association. He holds more than 50 U.S. patents and has coauthored two books, *Vehicle Safety Communications: Protocols, Security, and Privacy* (2012) and *IP-Based Next Generation Wireless Networks* (2004), both published by Wiley. He is an IEEE Fellow.

TOM COUGHLIN

LIVING IN THE CLOUDS


Tom Coughlin

Although today's consumer devices have more processing power, storage, and connectivity (or perhaps because of it), they are dependent upon applications and services run from remote data centers (the cloud). As connected intelligent consumer devices proliferate, there will also be demand for local-edge-computing resources (fog or edge devices like home gateways) that can provide local processing and aggregation services as well as protect the privacy of individuals. We will look at the trends in local connectivity and connected consumer devices, as these trends will drive a future that will safely incorporate the IoT into our homes, cars, clothes, and bodies.

Tom Coughlin, president of Coughlin Associates in Atascadero, California, is a widely respected digital-storage analyst as well as a business and technology consultant. He has more than 35 years in the data-storage industry, with multiple engineering and management positions at high-profile companies. Coughlin has many publications and six patents to his credit. He is also the author of *Digital Storage in Consumer Electronics: The Essential Guide*, published by Newnes Press.

Coughlin Associates provides market and technology analysis as well as data-storage technical and business-consulting services. He publishes the *Digital Storage Technology Newsletter*, the *Media and Entertainment Storage Report*, the *Emerging Non-Volatile Memory Report*, and other industry reports. He is also a regular contributor on digital storage for Forbes.com and other blogs.

Coughlin is active with the Society of Motion Picture and Television Engineers, the Storage Networking Industry Association, and other professional organizations. He is the director for IEEE Region 6 and active in the IEEE Consumer Electronics Society, where he is chair of the IEEE Future Directions Committee. He is the founder and organizer of the Annual Storage Visions Conference (www.storagevisions.com), a partner to the International Consumer Electronics Show, as well as the Creative Storage Conference (www.creativestorage.org).

He is the general chair of the annual Flash Memory Summit, a leader in the Gerson Lehrman Group Councils of Advisors, and a member of the Consultants Network of Silicon Valley. He is a Senior Member of the IEEE. For more information on Tom Coughlin and his publications, visit www.tomcoughlin.com.

DAVID BELANGER

BIG DATA AND THE FOG


David Belanger

We are on the verge of yet another quantum leap, enabled by new communications technology like 5G/software-defined networking/network functions virtualization/IoT, in the amount of data available for analysis. The technologies are typically oriented to using parallelism and distribution to manage scale and complexity without exploding cost, and they have matured into a second generation in which the tools, often open source, are accessible to a wide variety of users.

A number of examples of application types, e.g., detecting rare events or recommender systems, using big data that would have been too costly or too difficult prior to it have become commonplace. The leap in communication capability has also led to interest in fog computing for edge storage and analytics, which will add new applications while challenging the existing technologies and processes. This presentation looks at the potential interaction of evolving big-data techniques and distributing computing over a cloud-to-thing continuum.

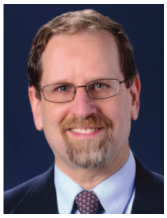
David Belanger is currently a senior research fellow at Stevens Institute of Technology in Hoboken, New Jersey. He works in big-data technology, applications, and governance and is a leader in the business intelligence and analysis master's degree program. He also leads the IEEE Big Data Initiative (bigdata.ieee.org).

He retired as chief scientist and vice president of information, software, and systems research of AT&T Labs of Florham Park, New Jersey. He created the AT&T InfoLab, an early participant in big data research and practice. He previously led the software engineering research department at Bell Labs in Murray Hill, New Jersey.

He earned a Ph.D. degree in mathematics from Case Western Reserve University, Cleveland, Ohio. His awards include the AT&T Science and Technology Medal for contributions in very-large-scale information-mining technology; AT&T Fellow for "lifetime contributions in software, software tools, and information mining"; and the IEEE Communications Society Industrial Innovator Award. He currently holds 31 patents.

ROBERT S. FISH

STANDARDIZATION OF FOG COMPUTING


Robert S. Fish

For the continued success of fog computing and networking, it may be necessary to standardize some elements of the technology. Standardization promotes interoperation and lowers costs for technology adoption on an industry-wide basis. The IEEE provides an end-to-end ecosystem for technology development that includes a globally recognized standardization process. Here we outline the paths through the IEEE standardization process that are open to participants in the fog technology universe.

Robert S. Fish is the vice president of Industry and Standards Activities of the IEEE Communications Society. He is the president of NETovations, LLC, Princeton, New Jersey, as well as a faculty member in the Computer Science Department of Princeton University. From 2007 to 2010, he was the chief product officer and senior vice president at Mformation, Inc., Edison, New Jersey. From 1997 to 2007, he was vice president and managing director of Panasonic U.S. research and development laboratories in Newark, New Jersey, working on embedding networking into consumer devices. He was previously the executive director, Multimedia Communications Research at Bellcore/Telcordia, Piscataway, New Jersey, after starting his career at Bell Laboratories, Murray Hill, New Jersey. In addition to his many publications, he has been awarded 17 patents. He earned his Ph.D. degree from Stanford University.

Magnetic Pixels: A World Beyond Touch Screens

By Alex Rubin

An unexpected byproduct of wireless power-transfer research resulted in a radically new method of display screen control. Research is seldom a linear process, but the implications of Pabellon's discovery were evident early on. This article presents the unusual way that a small team of Silicon Valley researchers made their discovery.

Touch-capacitance screens have revolutionized the way we interact with phones, computers, and the checkout at the grocery store. We put up with the fingerprint smudges and sticky surfaces for this convenience in our daily lives. The ability to integrate controls and displays in an easy-to-use way is nothing short of amazing. Is there something practical that comes next? Steven Spielberg's *Minority Report* gives a glimpse of the possibilities, but the technology required to achieve such is complex and very expensive.

Pabellon's primary research, since its founding in 2012, has focused on surface plane magnetic technology for nonradiative power and data transfer (ref 2016 IEEE article, "Rethinking Remote Power and Data Transfer" by Alex Rubin). In 2014, Pabellon achieved the milestone of powering of multiple consumer electronics devices over a large area of coverage. First a conference room table, then a warehouse floor area of coverage was shown to work viably for a number of use cases. This research had little to do with creating a touch-free world of displays. Primary research, however, seldom follows a straight path. Here is the serpentine trail that led Pabellon's small team of Silicon Valley researchers to discovery.


Large surface areas could be converted into efficient charging surfaces.

After successful demonstration that large surface areas could be converted into efficient charging surfaces, an unexpected side effect was uncovered. Tests revealed subtle fluctuations in magnetic-field strength during power transfer from transmitter to receiver loads. It was not evident what caused

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