AROUND THE WORLD OF IOT

In this column we plan to take a tour around different physical locations in the world with the objective of highlighting the peculiarities of the trendiest IoT-related applications in selected regions. Thus, the "IoT World" will certainly be physical, but traveling around it shall also expose to the readers how different application domains have been addressed, with particular attention to business sustainability.

Introduction

COLUMN EDITOR
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The world of IoT is also a place where new technologies get tested. For the IoT, like for all other application domains using the wireless communications spectrum, that world is getting more and more crowded, especially with 5G coming to maturity. In this column edition we take a closer look at the "mmWave Frontier", more specifically reporting from the recent Vertical Summit that covered discussions on topics related to what the future holds for the IoT in this frequency window above 30 GHz.

3rd Internet of Things (IoT) Vertical and Topical Summit

by Keith Gremban, University of Colorado Boulder and
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The 3rd IoT Vertical and Topical Summit, jointly sponsored by the IEEE IoT Initiative and the IEEE Microwave Theory and Techniques (MTT) Society, was held on January 26-27 at Radio and Wireless Week 2020 (RWW2020) in San Antonio, Texas. The topic this year was "IoT and the mmWave Frontier." mmWaves, the radio frequencies between 30 GHz and 300 GHz, open up a new frontier in communications and sensing for IoT. For example, mmWaves offer Gb/s bandwidth for communications, and high resolution in both range and angular accuracy for sensors. In addition, technologies for radio frequencies up to 1,000 GHz (1 THz) were addressed. Over 50 professionals from industry, government, and academia gathered together for a highly interactive session to discuss the role that mmWaves will play in IoT.

The Summit, which took place over one and one-half days, was organized into technical sessions consisting of several talks and a moderated panel discussion fielding questions from the audience. Sessions covered a range of topics designed to bring into focus the potential for mmWave and THz technologies for IoT, as well as operational, technical, and policy issues involving the licensing of mmWave spectrum:
- The Internet of Things (IoT) and future mmWave/THz technologies
- Practical, policy, regulatory, and legal Issues for mmWave and THz Technologies
- Applications for IoT technologies
- Meeting requirements for applications of mmWave technologies for IoT
- The role of mmWaves in 5G and IoT applications
- Applications in aerospace and defense

IoT is a complex ecosystem with many stakeholders, including consumers, researchers, industry verticals, standards bodies, regulators, and governments. IoT is a fast growing market, expected to be valued at USD $561.04 billion by 2022, according to MarketWatch,[1] which also forecast a compound annual growth rate (CAGR) of 26.9 percent. The number of IoT devices is similarly growing. The number of internet-connected devices exceeded the human population of ~7 billion sometime in the early 2010s, and some analysts forecast that the number of IoT devices will exceed 20 billion by the end of 2020,[2] meaning roughly three IoT devices for every person on Earth.

Combined with the sheer number of IoT devices, the trend for IoT is a transition to wireless connectivity. Indeed, over the past decade, as wireless communications has become ubiquitous, devices are increasingly connected to the Internet through a wireless link. A Bell Labs report[3] predicted that by 2025, over 90 percent of connections would be wireless. From a capital expenditures point of view, this makes sense, especially in dense urban and suburban environments, as wireless transmission reduces the costs associated with digging up streets and laying fiber.

The number of devices, combined with the growth in wireless communications, drives a need for spectrum to meet IoT requirements. So-called low-band and mid-band spectrum, 6 Ghz and below, is crowded and expensive. In 2015, the U.S. Federal Communications Commission (FCC) auctioned off 65 MHz of sub-6 GHz spectrum for nearly USD 44.9 billion. Much more spectrum is available in the mmWave frequencies. For example, in 2016, the FCC adopted rules to free up nearly 11 GHz of mmWave spectrum for wireless broadband use. These higher frequencies are capable of very high speed and high capacity communications. 5G exploits mmWave to achieve Gb/s speeds.

But applications of mmWaves are not without their challenges. mmWaves have different propagation properties than do low-band and mid-band frequencies. In particular, mmWaves are subject to much greater atmospheric attenuation; as frequencies increase, radio waves exhibit less diffraction, meaning that shadowing is more prevalent; and many building materials such as concrete are essentially impenetrable to mmWaves, as is the human body. On the other hand, mmWaves reflect off many materials, which can offset the lack of diffraction in many scenarios. An advantage of mmWave propagation is that exterior building materials are relatively impenetrable, while indoor materials are not. Hence, interior mmWave deployments are effectively isolated from exterior interference and vice versa. mmWave beamforming can be used to overcome attenuation issues and can provide high-bandwidth interconnects at short to moderate ranges. For example, IEEE 802.15.3c (WiGig) is a wireless interconnect protocol that uses 60 GHz mmWave frequencies and can support up to 6 Gbps connections. However, efficiency is an issue. Currently, high bandwidth mmWave circuits operate at about 2 percent efficiency and require significant heat dissipation.

mmWave radar applications are also increasing. The high resolution of mmWave radars offers new sensing dimensions and modalities. With mm-range resolution, radars are not limited to detection of bulk objects, but can be used for finer resolution tasks, such as gesture recognition. However, much work remains to be done in detecting and resolving objects in natural environments.

The technology to exploit frequencies above mmWave, 300 GHz to 1 THz, is also advancing. Because of attenuation losses, THz frequencies are impractical for terrestrial communications, but show great promise for space-to-space, air-to-air, and air-to-space. Pointing and tracking is still a challenge, but the potential

FIGURE 1. Adam Drobot (left) and Charlie Jackson (right), along with Robert Caverly (not pictured) organized the 3rd IoT Vertical and Topical Summit.

payoff in bandwidth is high. Early demonstrations of THz communications have shown 100 Gbps links at distances of less than 600m. THz radars will have very high resolution, but short range if used terrestrially.

The Summit concluded with an open discussion of the state of IoT and the role of the IoT Initiative. Roughly 60 verticals exist in the economy, most of which incorporate IoT technologies. Perhaps because of the number of verticals, no general architectures span the IoT space. Hence, deployments tend to be unique. The community needs a set of architectural patterns that can guide and simplify deployments. Cost is king! Economics drives everything! To truly digitize the planet with IoT devices, the cost per device must drop down to single digits in USD.

The Summit program and copies of all presentations can be found at https://rww2020.iot.ieee.org/program/

Biographies

Keith Gremban (kdgremban@gmail.com) is a Research Professor in the Technology, Cybersecurity, and Policy (TCP) Program at the University of Colorado Boulder. He has been involved in systems engineering and advanced technology development for over 30 years. Prior to joining the University of Colorado, he was the Director of the Institute for Telecommunication Sciences (ITS), which is the research and engineering laboratory for the National Telecommunications and Information Administration (NTIA). He was also a Program Manager at the Defense Advanced Research Projects Agency (DARPA), where he managed a portfolio of programs in the areas of wireless communications and electronic warfare. Prior to DARPA, he worked at a variety of companies and research organizations, managing and leading research and systems engineering projects, including a diverse collection of unmanned systems and command-and-control applications. He received his Ph.D. and M.S. in computer science from Carnegie Mellon University, and his M.S. in applied mathematics and B.S. in mathematics from Michigan State University.

Adam Drobot is a technologist with management expertise and over forty years of experience with business, government, and academia. Today his activities include strategic consulting, start-ups, and participation in industry associations and government advisory bodies. He is the Chairman of the Board of OpenTechWorks, Inc. a company specializing in open source software. Previously he was the Managing Director and CTO of 2M Companies in Dallas, TX, from 2010-2012, and President of the Applied Research and Government Business Units at Telcordia Technologies and the company's CTO from 2002 to 2010. Prior to that, Adam managed the Advanced Technology Group at Science Applications International Corporation (SAIC). He also served as Senior Vice President for Science and Technology as part of his 27 years of service at SAIC from 1975 to 2002. He has been the principal or key participant in the development of several large, scientific code systems and software for managing the design and production of complex platforms. He has published more than 100 journal articles, and is a frequent contributor to industry literature. He currently holds 26 patents. Adam is the 2007 recipient of IEEE's Managerial Excellence Award. He is currently a member of Several Corporate Boards, the FCC Technology Advisory Council, and he also Chairs the Awards Recognition Council for the IEEE and the IEEE IoT Activities Board. Adam is on the Board of the Telecommunications Industry Association and Chairs the TIA Technology Committee. He holds a BS in Engineering Physics from Cornell University and a PhD. in Plasma Physics from the University of Texas.

FIGURE 2. Chulong Chen (left), Omeed Momeni (left center), John Graybeal (right center) participated in a panel on Applications for IoT Technologies moderated by Adam Drobot (right).

Column Editor Biography

Raffaele Giaffreda (rgiaffreda@fbk.eu) is a chief IoT scientist at FBK CREATE-NET, Italy. He has worked in the telecom R&D environment since the beginning of his career, focusing in the last decade on IoT and related technology transfer activities. In his role, he is now responsible for setting research and innovation directions, acquisition of funding, and the execution of a number of collaborative projects in the IoT domain. He has worked in Italy and the United Kingdom (10 years), acquiring experience in both corporate telco environments (R&D of BT and Telecom Italia) as well as in a small research organization (CREATE-NET before its merger with FBK), where the ability to acquire funding was key to ensuring continuity of operations. He is a recognized expert with a substantial record of IEEE publications and conference presentations, a patent, and various book chapters and tutorials on IoT. He is an experienced speaker and chair of IoT related events, serves as an EU reviewer, has served on the TPCs of a number of international conferences, and he is the Editor-in-Chief of the *IEEE IoT Newsletter*.

FOOTNOTES

1 https://www.marketwatch.com/press-release/internet-of-things-iot-market-growing-at-cagr-of-269-key-players-intel-corporation-sap-se-cisco-microsoft-oracle-2020-01-17

2 https://www.gartner.com/en/documents/3597469/forecast-analysis-internet-of-things-endpoints-worldwide

3 M. K. Weldon, The Future X Network: A Bell Labs Perspective (2016)