Chih-Lin I, Mikko A. Uusitalo, and Klaus Moessner

The 5G Huddle

During the summer and autumn of 2014, the Wireless World Research Forum (WWRF) was involved in a wide range of activities related mostly to progressing the global discussion on the development of fifth-generation (5G) concepts.

Most significantly, on 22–23 September, WWRF, in conjunction with techUK hosted "The 5G Huddle—Towards a Global 5G Vision," involving two days of interactive discussion aimed at bringing together senior industry and government leaders from North America, Europe, and Asia. The meeting certainly brought out the vision of the future, where the Internet of Things (IoT) and people integrate with new services ranging from medical applications to smart energy, smart buildings, robots, autonomous driving vehicles, and drones, and much agreement emerged from discussions among leading experts from government, industry, and academia from Europe, North America, and Asia.

The key issues that emerged around the development of 5G technology were the IoT, spectrum management, data security, privacy, regulation, and competition as well as new business operating models. This future technology will be realized by the integration of technologies and applications on a range of infrastructures from fiber optics to wireless and satellites.

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During the event, Ed Vaizey, the United Kingdom's digital economy minister, announced a new program, The Future Technologies Network, which is focused on promoting innovation to encourage technology growth. The network will be hosted by techUK, the leading technology trade association. Speaking at a reception to mark the first anniversary of the U.K. Spectrum Policy Forum at the conference, he said, "The private sector is vital; you hold the answers." In addition, he announced funds to add to those provided by wireless companies to aid the studies needed to underpin the work of the U.K. Spectrum Policy Forum.

"The most powerful thing governments can do is to bring people together," added Simon Towler, deputy head of Telecommunications Policy, United Kingdom. "We encourage collaboration, the key watchword to enable 5G development, and SMEs can have a big role to play," he said. He also announced that to underpin the development of 5G technology, the government is to release 500 MHz of spectrum between 400 MHz and 5 GHz for public use by 2020, with the next major release coming from the current military users of 2.3 and 2.4 GHz. "Our spectrum strategy is underlying our commitment—dynamic spectrum access will underpin 5G," he said. Other initiatives in the radio sector include joint Anglo-German research between the Universities of Surrey, Kings College London, and the University of Dresden into 5G as well as work on the crossover between 5G and IoT.

David Willetts, a member of Parliament and former Minister for Universities and Science, said that "there clearly are enormous opportunities" in 5G, beyond the volume and speed of downloading material. "For me it is this wider opportunity of Internet of Things, which really is significant, and that's what's caught our imagination in government. I want the UK to be one of the world leaders in 5G and that's why we're trying to take advantage of being early movers in this space," he said. But he also warned about the risks of the Internet permeating our life, the biggest being around privacy and security. "Privacy fears must be addressed head-on to ensure development is not stifled," he said.

"We can only begin to imagine what more is coming," said Hamadoun Touré, secretary general, International Telecommunication Union, speaking by a video link. The 5G technology will have to support a variety of applications and environments, very high system capacity, and extremely high data rates; cut costs; make systems more robust; provide a higher level of security; and make more efficient use of

spectrum. Touré expects a framework for future IMT development to be finalized in 2015.

Prof. Rahim Tafazolli, director of the Centre for Communication Systems Research, University of Surrey, stressed the importance of a wider range of technological developments underpinning 5G capabilities, the key one being energy efficiency: "5G will be 100 times more efficient than 4G," and to ensure that 5G will work with everything within the IoT: "Everything on the Internet is important," he said. Prof. Tafazolli, however, warned against "speed at all costs" but rather underlined "user experience" and "perceived speed" as a priority. From the user perspective, he noted that there is no real value in "downloading a movie in one second that then you watch in three hours." The 5G technology is more than just cellular. It "will set a new paradigm of thinking," moving us on from mobile systems that were based on second generation (2G). In one sentence, he said, 5G is "always sufficient rate" to give users the perception of "infinite capacity." "My plea to the ITU: don't set 5G at higher speed," said Prof. Tafazolli.

Prof. Mischa Dohler from King's College London said that the speeds and capacity of 5G are likely to be beyond the needs of consumers. We see a "tectonic shift" as to who will be the final service client for 5G and foresee that the service opportunities in the future will not be with the consumer but with industry, particularly in sectors such as oil and gas, construction, nuclear energy, and transportation.

"What we call 5G should be renamed 5G Era because that is a wide sense of 5G," said Chih-Lin I, chief scientist of wireless technologies of China Mobile, which, with close to 800 million subscribers, is the largest telecom operator in the world. "In the past, we talked about 1G, 2G, 3G, and 4G in a quite narrow sense of next-generation mobile standards," she pointed out, and what is envisioned may come from multiple infrastructures, not just a single one. She forecast changes in a number of areas, including antenna, infrastructure, and spectrum. Together, she said, they represented "pearls for 5G."

Representatives from China, Korea, and India emphasized the key role these regions are playing in developing 5G. Thibaut Kleiner, head of the Network Technologies Unit at the European Commission dealing directly with 5G matters, said that the European Union (EU) wants to act as a bridge between regions to develop a global standard. The EU envisages the role of the regulator not to stifle innovation but to ensure the efficiency of the 5G rollout.

The 5G Huddle was immediately followed by the 33rd WWRF (WWRF33) meeting, hosted by the University of Surrey in Guildford, United Kingdom. WWRF33 featured high-profile speakers from industry, academia, and government, who discussed the user and societal aspects, technologies, applications, and regulatory environments necessary to develop the wireless-enabled smart societies of the 2020s. There were plenary sessions that debated the evolutionary paths toward 5G and technically focused working group sessions. The detailed program can be found at www.wwrf33.ch.

A special workshop was held between the 5G Forum, Korea, and WWRF to understand the scope and progress of 5G activities in Korea and to identify opportunities for 5G research collaboration between WWRF and 5G Forum members.

Another featured workshop was held with the Digital World Research Centre at the University of Surrey. This is a multidisciplinary research center that works on understanding the social impact of new technologies and understanding new forms of digital media production and consumption and developing ways of supporting them with novel media genres, formats, devices, and services in different cultural contexts around the world. It works with individuals, families, and communities on the use of self-made media and arts practitioners on the generation of professional media. The center was introduced by its director, David Frohlich.

Forthcoming meetings for WWRF include the next full meeting, to be held in Santa Clara, California, on 21–23 April 2015 and hosted by HP, and our next European meeting on 20–22 October 2015 at the University of Aalborg in Copenhagen, Denmark. In addition, WWRF is planning special workshops at significant conferences in 2015, such as HICSS2015 in Hawaii on wireless services and applications beyond 2020, and at the IEEE Vehicular Technology Conference in Glasgow.

In the past six months, WWRF published three white papers in its *Outlook* series based on contributions to the meetings and the work of editors. White papers have often proved to be a good starting point for new research and development projects. Production of the white papers is organized by the working group chairs, and once they are approved by the WWRF Steering Committee, they are published as an edition of WWRF *Outlook* on the WWRF Web site (www.wwrf.ch):

- *Outlook* September 2014, no. 14: "User 2020 A WWRF Vision"
- *Outlook* August 2014, no. 13, "A User Perspective on Social Networking Sites"
- *Outlook* July 2014, no. 12, "Smart Cities and the Ageing Population."

Our next publication, *Outlook* no. 15, which studies the issue of dual connection in small cells, will be published shortly, and further white papers on the 5G vision and radio technologies for 5G are near completion.

From the presentations and accepted articles, the following four best articles have been selected by at least three independent reviews from us for this special edition. The subjects range from requirements for 5G, architectural issues for 5G,

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and up to services. In addition, an approach about offloading of data in the Wi-Fi band for long-term evolution (LTE), which might also be useful for 5G, is presented.

The first article "Horizon 2020 and Beyond" is presented by David Soldani from Huawei European Research Institute, Germany, and Antonio Manzalini from Telecom Italia, Italy. Here an overview of 5G, the generation after 3G (UMTS), and 4G LTE is given.

Key performance indicators of 5G include increased throughput (1,000× more in aggregate and 10× more at link level), reduced latency (1 ms for remote control of robots or tactile Internet applications and below 5 ms for 2–8-K change in view at 30–50 Mb/s), and improved coverage (seamless experience), as well as battery lifetime (10× longer).

Further on, an overview of key enabling technologies to address the key performance indicators include filter bank-based multicarrier and universal filtered multicarrier as good examples of enabling technologies for both out-of-band interference control or software-defined networking (SDN) using OpenFlow. Finally, application scenarios, including device-to-device proximity services, are presented.

The next article by Anwer Al-Dulaimi, Saba Al-Rubaye, Qiang Ni, and Elvino Sousa from the University of Toronto, Canada, Stony Brook University, New York, and Lancaster University, United Kingdom, respectively, is titled "5G Communications Race."

This article is about the combination of technologies, LTE operating in the unlicensed band (LTE-U, currently discussed in 3GPP under the name of licensed-assisted access) using LTE features such as carrier aggregation allowing to offload data in the Wi-Fi band to maximize the spectral efficiency and throughput.

The article "Future RAN Architecture" is provided by Zainab Zaidi and Vasilis Friderikos from Kings College London, United Kingdom, and Muhammad A. Imran from the Institute for Communication Systems, 5G Innovation Centre, United Kingdom.

In this article, the potential of an integrated deployment solution for energy-efficient cellular networks combining the strengths of two very active currently research themes, software-defined radio access networks and decoupled signaling and data transmissions or beyond cellular green generation architecture for enhanced energy efficiency, is identified and studied.

In the last article, Kostas Tsagkaris, Marios Logothetis, Vassilis Foteinos, George Poulios, Michalis Michaloliakos, and Panagiotis Demestichas from the University of Piraeus, Greece, present "Customizable Autonomic Network Management" In this article, further results and visions for using autonomic network management and SDN, also based on open flow, are presented.

Author Information

Chih-Lin I is the China Mobile chief scientist of wireless technologies, in charge of advanced wireless communication research and development (R&D) effort of the China Mobile Research Institute (CMRI). She established the Green Communications Research Center of China Mobile, spearheading major initiatives, including fifth-generation key technologies R&D; high energy efficiency system architecture, technologies, and devices; green energy; C-RAN; and soft base station.

She received the Ph.D. degree in electrical engineering from Stanford University and has almost 30 years of experience in the wireless communication area. She has worked in various world-class companies and research institutes, including the wireless communication fundamental research department of AT&T Bell Labs; the headquarters of AT&T, as director of wireless communications infrastructure and access technology; ITRI of Taiwan, as director of wireless communication technology; Hong Kong ASTRI, as vice president; and the founding GD of the communications technology domain.

She received the IEEE Transactions on Communications Stephen Rice Best Paper Award and is a winner of the CCCP National 1000 talent program. She was an elected board member of the IEEE Communications Society (ComSoc), chair of the ComSoc meeting and conference board, and the founding chair of the IEEE WCNC Steering Committee. She is currently the chair of the Future Forum 5G SIG, an executive board member of GreenTouch, and a network operator council member of ETSI NFV.

Mikko A. Uusitalo is a research leader at Nokia Technologies in the area of fifth generation (5G). Currently, he is also the WP5 spectrum leader in METIS. He obtained the M.Sc. (Eng) and the Dr.Tech. from the Helsinki University of Technology in 1993 and 1997, respectively, and the B.Sc. (economics) from the Helsinki School of Economics in 2003. (Both of these are currently known as Aalto University.) He has been at Nokia since 2000 with various roles, including principal researcher and head of international cooperation at Nokia Research.

In 2001, he was the project manager of the Wireless Strategic Initiative that gave birth to the World Wireless Research Forum (WWRF), a new type of successful cooperation between and within industry and academia in the area of identifying research topics and cooperation in wireless communications. He was elected chair of WWRF for the years 2004–2006. He is also a founding member of the CELTIC EUREKA initiative. He is a Senior Member of the IEEE.

Klaus Moessner is a professor in mobile communications in the Institute for Communication Systems at the University of Surrey, United Kingdom. He earned the Dipl-Ing (FH) from The University of Applied Sciences in Offenburg, Germany; the M.Sc. from Brunel University, United Kingdom; and the Ph.D. from the University of Surrey, United Kingdom.

His research interests include reconfigurability on different levels, including object and function virtualization, management, and control of virtualized resources, and cognitive networks. The interests map to the crowd sensing, activity and situation recognition, and cognitive systems areas, and the smart city and smart transport domains. He is involved in the investigation and teaching of mobile operating systems, mobile service platforms, service-oriented architectures, mobile service delivery, and service enablers.

He has been involved in different roles in many U.K.- as well as European community-supported research projects in the area of the Internet of Things. This includes the projects EyeHUB, M:Ciudad, OUTSMART, iCore, Probe-IT, IoT. est, COSMOS, SocIoTal, iKAAS, and FrontierCities.

He leads the work area on system architecture and coexistence in the Fifth-Generation Innovation Centre at the University of Surrey. ***VT***

TRANSPORTATION SYSTEMS *(continued from page 22)*

The PKP Pendolino has seven cars and can carry up to 402 people in three classes: first, second, and dedicated closed compartments for families. The cars are all equipped with air conditioning, passenger information on light-emitting diode screens, table and electrical sockets for each passenger, high luggage capacity, and bicycle storage.

InterCity Express (EIC) Premium is the most comfortable train category that PKP Intercity offers its passengers. It is also a whole new dimension and standard of traveling in Poland because PKP's ultimate goal is the convenience and safety of the passenger. Premium EIC trains connect north and south Poland, operating between Tri-City, Warsaw, Krakow, Katowice, and Wroclaw.

Tickets are available over the counter, from ticket machines, on the Web site, and through mobile applications. They cannot be purchased on the train from the conductor.

First-class passengers receive a meal and two drinks of their choice, while second-class passengers receive a snack and a choice of one drink.

The new trains have been adapted to the needs of people who are blind or visually impaired. For example, the seats are marked in Braille. For people with reduced mobility, a ramp supported by the staff of the train has been supplied.

The commissioning of the new Pendolino trains follows a contract worth €665 million awarded by PKP Intercity in 2011 to supply 20 high-speed trains, the full maintenance of the fleet for up to 17 years, and the construction of a maintenance depot in Warsaw.

In September 2014, the Polish Office of Rail Transport, responsible for the supervision of the railway sector's safety in Poland, certified the Pendolino trains. During the tests, the Pendolino beat its own speed record with a speed of 182 mi/h, establishing Poland's highest ever speed record on rail.

The European Union (EU) is supporting sustainable transportation initiatives and allocated €74 million for this high-speed project in Poland. An additional €10 billion will be granted within the EU cohesion fund 2014–2020 to further support the development of the Polish railway network. With over 2,500 mi of track, Poland has the third biggest railway network in Europe. ***VT***

CONNECTED VEHICLES *(continued from page 27)*

with real-time conditions to provide travelers with the best travel time estimates for their destination. Drivers using Predictive Traffic saw estimated arrival times that were up to 20% more accurate for journeys over 30 min in length.

Automakers, transportation agencies, and other companies can build applications that seamlessly integrate HERE predictive traffic data across all screens. Preplanned trips could be synced to the cloud, e.g., allowing for automatic integration with the car and real-time notifications via connected devices. Dynamic message signs on highways could broadcast better travel times to the public. The product will initially be available to original equipment manufacturers in the United States, Canada, and Germany. ***VT***