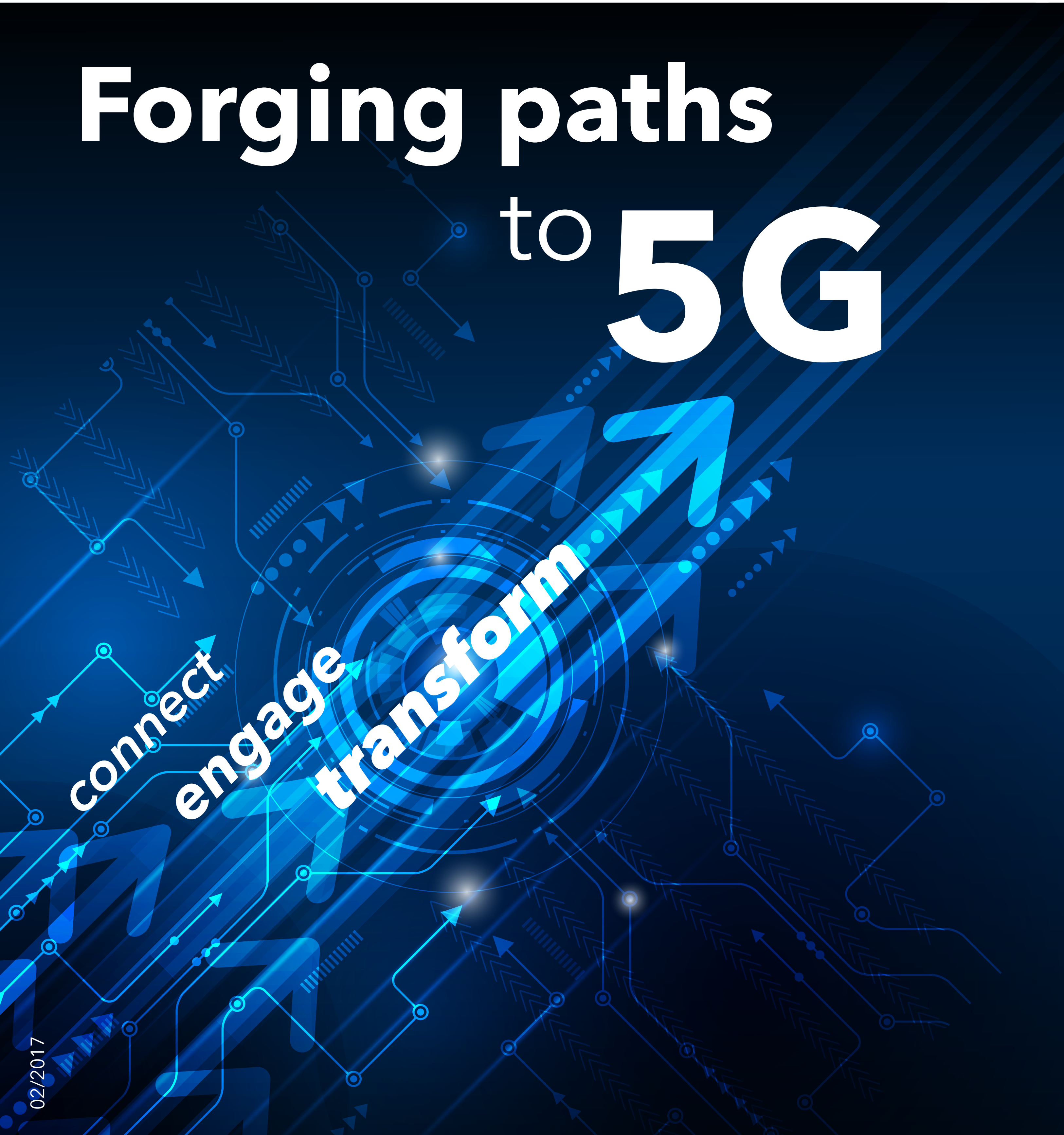
ITUNews MAGAZINE

Forging paths to 5G



02/2017

Why the world needs 5G

Houlin Zhao, ITU Secretary-General

5G is coming fast, and it will have great power to transform our lives for the better.

Fifth-generation "IMT-2020" technology (5G) is coming fast, and it will have great power to transform our lives for the better.

Better health care, smarter cities, vastly more efficient manufacturing are all being made possible as the "Internet of Things" era gathers pace with an array of innovative solutions that are powering our modern economy. But none of these things can reach their full potential without 5G networks. Indeed, smart 5G systems will soon be essential to meet the data-intensive demands of billions of people who are using ever-growing amounts of video daily.

5G will bring much faster data speeds, reliable connectivity and low latency to international mobile telecommunications (IMT) – all needed for our new global communications ecosystem of connected devices sending vast amounts of data via ultra-fast broadband.

This edition of ITU News will lay out what 5G is – why it carries such promise – and how to make such complex systems a reality.

There is a great opportunity in these early stages of 5G development to apply the lessons of past experiences building 3G and 4G/LTE systems. These pages will outline ITU's role in adopting the globally harmonized spectrum and standards that will facilitate the development and implementation of 5G. This edition of ITU News will also offer solution-oriented insights from a range of thought leaders on key aspects of 5G, such as network slicing, Information-Centric Networking (ICN), and open source projects – among many others. Please read on to learn more about 5G, the backbone of tomorrow's digital economy.

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Editor-in-Chief: Matthew Clark
Art Editor: Christine Vanoli
Editorial Assistant: Angela Smith

Editorial office/Advertising information:
Tel.: +41 22 730 5234/6303
Fax: +41 22 730 5935
E-mail: itunews@itu.int

Mailing address:
International Telecommunication Union
Place des Nations
CH–1211 Geneva 20 (Switzerland)

What is 5G?

What could 5G bring to you?	What's new with 5G?	Why not today?
Amazing volume, amazingly fast	Spectrum extension; millemetre waves; cell densification; increased spectrum efficiency; advanced antennas; 3D beam-forming techniques; new electronic components; backhaul optimization; D2D; moving networks (vehicle-based cells)	Spectrum saturation; limited spectrum aggregation; current hardware not able to function at high frequencies; expensive deployment and maintenance of small cells
Always best connected	Combination of 4G, 3G, Wi-Fi, and new radio access to create an integrated and dynamic radio access network; connectivity management mechanisms	Seamless handover (e.g. cellular to Wi-Fi) not supported
No perceived delay	Ultra-low latency; software-defined networks; decoupling functional architecture from the underlying physical infrastructure; network intelligence closer to users; mobile edge computing (MEC); D2D	4G latency ≥ 10ms
Massive amounts of connected things and people	New waveform; cell densification; much less signalling traffic and no synchronization; radio access network (RAN) architecture	Current frequency-division multiplexing (FDM) waveform limitations; interference prevents scaling up; 4G chipset cost; energy consumption
Energy efficiency	Millimetre waves for front-haul and backhaul; new operation mechanisms for dense networks; pooling of base station processing; on-demand consumption; massive machine communications; power amplifiers; digital signal processing (DSP) – enabled optical transceivers; harvesting ambient energy; optimization of sleep mode switching	Base stations' idle time not optimized; unused functions activated; air interface/ hardware not energy optimized
Flexible, programmable networks	Software-defined networks; network function virtualization; decoupling functional architecture from the underlying physical infrastructure; application program interfaces (APIs)	Many various network management software; not interoperable; bundling of network functions in hardware boxes
Secure networks	Physical channel authentication; virtualized authentication	Security as add-on not by design; fragmented approach

Source: European Commission 2015.
A Digital Single Market Strategy for Europe

5G in an ideal world

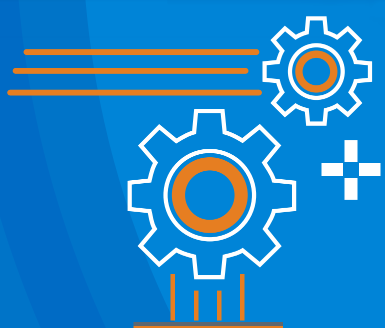
Transport

- Transport data flows freely between once closed sub-transport sectors
- Opportunities for new collaborations and applications
- The delivery of a true Internet-of-Things experience connecting everything on the road
- Data and advanced data products are acknowledged by all stakeholders and protected as the fuel in the new value chain
- Transport data sharing and access is fundamental

Automotive

- The industry is open to change
- New business models emerge
- High trust from users and related sectors
- Effective governmental frameworks and standardization

Utilities



- High levels of connectivity supported by a strong regulatory environment
- There is inter-vertical and cross-vertical collaboration
- There is interoperability and integration
- A new ecosystem of devices and networks is designed to meet user needs

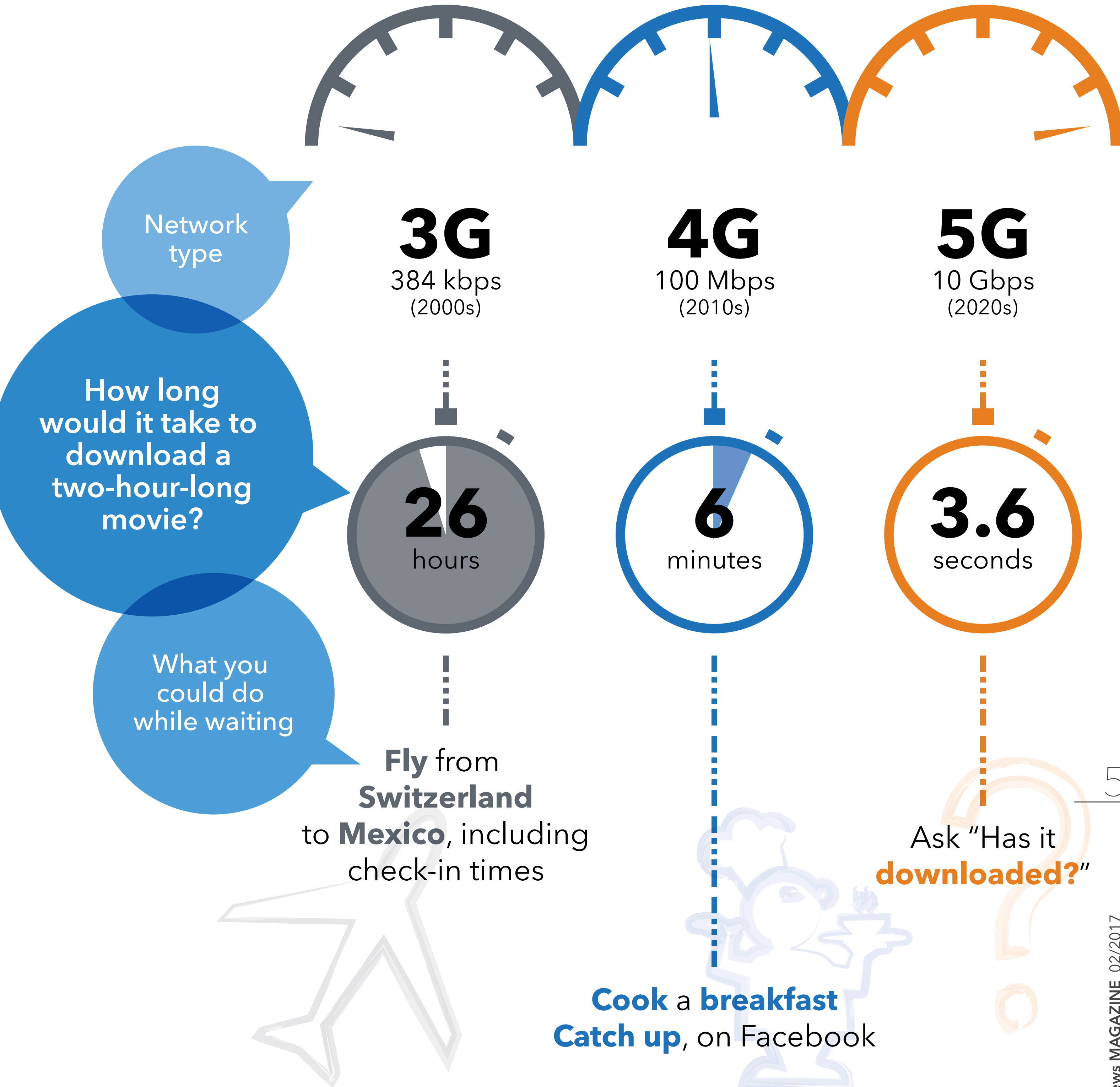
Health care

- Widespread acceptance of technology-driven innovation
- Health practitioners are open to change
- New emerging business models which are supported by strong, clear regulations
- Health care involves preventing illness and not just treating illness
- Health care involves enhancing wellbeing and quality of life

The above shows results of scenario development activities at workshops led by the European Commission.

Source: European Commission 2015.
A Digital Single Market Strategy for Europe (Chapter 5)

Looking forward to 5G video



5G Video insights

What is 5G?

5G Shift: The connected lifestyle

Wireline technology enablers for 5G

See more **ITU 5G use case demos**

5G in action: KT's plans to showcase 5G

Dongmyun Lee

Chief Technology Officer,
KT, Republic of Korea

Today we are witnessing the start of an unprecedented smart revolution driven by the latest advanced digital and mobile technology: 5G.

5G promises to deliver higher data rates, lower latency, and more reliable connectivity. In a sense, these improvements are already happening, at a slow, but steady pace, through existing technologies and services, such as fourth-generation long-term evolution (4G LTE), fixed-broadband service, WiFi, and the Internet-of-Things (IoT).

Once 5G technology is commercialized, however, these new applications will come in much greater variety, with enhanced precision — and the speed of change will be much faster.

5G technology is forecasted to provide 100 times faster data speeds than the current 4G LTE technology. It is also expected to enable network connectivity with ultra-low latency equal to less than one-tenth that of present communication systems. It will also make massive connectivity possible, so that hundreds of thousands of devices can be connected to a cell simultaneously.

> ***"We are witnessing the start of an unprecedented smart revolution driven by the latest advanced digital and mobile technology: 5G."***
>
> Dongmyun Lee


Shutterstock

At the same time, 5G capabilities will be integrated with the cloud, artificial intelligence (AI), big data and IoT, thereby leading the conventional industry and society into the automated and intelligent world.

5G will enable the mobile communication industry to broaden the scope of applications to include important enhancements to physical infrastructure such as roads, harbours, and transportation systems. Indeed, 5G will propel tomorrow's digital economy, and information and communication technology (ICT) providers will play a central role.

KT's 5G at the Pyeongchang Winter Olympics

KT aims to be a leader in 5G, and has a clear, substantial, and concrete management agenda called "**GiGAtopia**", which is currently in the development and deployment stages. For example, our GiGA Internet, based on the ITU Telecommunication Standardization Sector (ITU–T) **G series Recommendations**, and GiGA LTE, based on the ITU–T **Y series**, are already being provided to more than 2 million subscribers. KT is moving ever closer to the 5G era through an accumulation of experiences and capabilities on infrastructure and services.

Based on these experiences and capabilities, KT's CEO announced during his keynote speech at the Mobile World Congress this year that the launch of 5G commercial services would take place in 2019. He also promised that KT would show how 5G will change the world at the Pyeongchang Winter Olympics in 2018.

To this end, KT has been devoting a lot of time and effort to developing new devices and services, as well as network systems, to showcase a variety of 5G applications at the Pyeongchang Olympic Games. Immersive media applications like "Omni-View" and "Sync-View" are a few examples of these services, which will enable a new sports viewing experience, as well as 5G autonomous vehicles. KT's 5G display at the Olympics will aim to show people all over the world how to experience the changes that 5G and ICTs will bring about in the near future.

The power of networks for converging industries

KT is not only preparing for the 5G era with telecommunication services, it is also actively striving to converge other industries, such as energy, automobile, agriculture, medical, etc. For example, KT is providing the "KT-MEG" (Micro Energy Grid) service, which remotely manages tens of thousands of customers' energy usage, automatically, with a communication network. Usage prediction based on big-data analysis, can, for instance, improve power plant productivity. KT has also developed applications in other areas – from automobile insurance rates to avian influenza prevention, and many more.

> ***"Creative ideas will play the most crucial role in making 5G a highly important platform for societal changes and a new digital economy."***
>
> Dongmyun Lee

What is crucial for the 5G revolution?

Realizing those future experiences in an increasingly interconnected world will, of course, require a higher level of stability, security, and reliability. There are also a number of technical and regulatory issues that need to be solved to overcome threats such as hacking, system fault management, and high costs due to complex operations. In order to make this new industrial revolution happen, based on 5G technologies, these obstacles need to be removed. We share a general belief that such problems will be overcome. Human beings have in the past always found solutions through creative ideas and cooperation. Indeed, creative ideas will play the most crucial role in making 5G a highly important platform for societal changes and a new digital economy.

Standards and spectrum for international mobile telecommunications

François Rancy

Director, **ITU Radiocommunication Bureau**

The dramatic increase in availability and accessibility of mobile communications in recent years is due, to a large extent, to the development of international standards and the identification and global harmonization of frequency bands for the operation of international mobile telecommunications (IMT), thereby enabling interoperability, roaming and global economies of scale.

Standards

Second generation mobile telephone systems were developed in the late 1980s and initially deployed in the early 1990s. The transition from the first to the second generation of mobile phones was certainly characterized by the change from analogue to digital communications, but it was also characterized by the growing requirement for these systems to operate seamlessly on a regional, if not global, basis.

> ***"ITU's work in developing the standards for IMT-2020, in close collaboration with the whole range of 5G stakeholders, is now well underway."***
>
> François Rancy

ITU's role in the path to 5G

For over 30 years, ITU has been developing, and continues to develop, the standards and spectrum arrangements to support International Mobile Telecommunications (IMT).

1970s [1G]

First generation

First generation (1G) analogue systems for mobile communications saw two key improvements to the first radiotelephone services: the invention of the microprocessor and the digitization of the control link between the mobile phone and the cell site.

1980s–1990s [2G]

Second generation

Second generation (2G) digital cellular systems were first developed at the end of the 80s and initially deployed in the early 90s.

These systems digitized not only the control link but also the voice signal. The new system provided better quality and higher capacity at lower costs to consumers.

Regional/global operation of these systems was hampered by having multiple incompatible standards as well as different frequency bands and channel arrangements being used in different parts of the world.

A historic decision was taken at the ITU World Administrative Radio Conference 1992 (**WARC-92**) to identify globally agreed frequency bands for the operation of future public land mobile telecommunication systems – now called international mobile telecommunication (IMT) systems – in the Radio Regulations.

Regional/global operation of these systems was hampered by having multiple incompatible standards as well as different frequency bands and channel arrangements being used in different parts of the world. This in turn had a significant impact on the cost, and hence affordability, of these systems. Recognizing this, the ITU membership established a group of experts to study the requirements of future public land mobile telecommunications systems (FPLMTS).

Studies on FPLMTS were conducted in the CCIR (the former ITU Radiocommunication Sector (ITU–R)) Interim Working Party 8/13, with the first substantive outcome being a decision by the 1992 World Administrative Radio Conference to identify specific frequency bands for the operation of FPLMTS. The studies then focused on developing the set of detailed radio interface specifications for FPLMTS.

ITU–R Task Group 8/1 was established to develop these 3G radio standards, which were finally approved in May 2000 in Recommendation ITU–R **M.1457** – "Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)". The name change from FPLMTS to IMT and the principles and process for the further development of IMT were established by the ITU Radiocommunication Assembly 2000 in ITU–R Resolutions **56** and **57**.

ITU–R Working Party 5D was subsequently established to continue the work on IMT. In close collaboration with the relevant national and regional standards development organizations, a yearly update process for IMT-2000 was applied to cater for the evolution and enhancement of the standard.

ITU–R Recommendations were also developed to address the implementation aspects of IMT-2000 such as global circulation of terminal equipment, radio frequency channel arrangements and sharing studies between IMT and other radio services.

At the same time, ITU–R Working Party 5D initiated work to address the need for a global platform on which to build the next generation of mobile services – fast data access, unified messaging and broadband multimedia: IMT-Advanced. The IMT-Advanced radio interface specifications were finalized in 2012 and are specified in Recommendation ITU–R **M.2012**. These 4G systems are currently being deployed throughout the world, and it is expected that these systems will continue to evolve and be enhanced in the coming years.

With an eye to the longer term requirements, in 2012 Working Party 5D commenced studies on the next phase of development: IMT-2020. It is planned to finalize the IMT-2020 specifications (5G) in the year 2020.

Spectrum

Where radio systems are to be used globally, it is highly desirable for existing and newly allocated spectrum to be harmonized. The benefits of spectrum harmonization include: facilitating economies of scale, enabling global roaming, reducing equipment design complexity, preserving battery life, improving spectrum efficiency and potentially reducing cross border interference.

2000s [3G]

Third generation

After over ten years of hard work, the ITU Radiocommunication Sector (ITU–R), in close collaboration with national and regional standards development organizations, finalized the technical standards for the radio interfaces of third generation systems under the brand IMT-2000.

ITU's IMT-2000 global standard for 3G was unanimously approved at the ITU Radiocommunication Assembly 2000 (**RA-2000**), which opened the way to enabling innovative applications and services (e.g. multimedia entertainment, infotainment and location-based services, among others).

2012 [4G]

Fourth generation

Specifications for fourth generation mobile technologies – IMT-Advanced – **were agreed** in January 2012 at the ITU Radiocommunication Assembly (**RA-12**) in Geneva.

IMT-Advanced systems include the new capabilities that go beyond IMT-2000, providing access to a wide range of telecommunication services supported by mobile and fixed networks, which are increasingly packet based.

2012–2020 [5G]

Fifth generation

In early 2012, ITU–R embarked on a programme to develop "**IMT for 2020 and beyond**", setting the stage for 5G research activities that were emerging around the world.

In September 2015, ITU–R finalized its "Vision" of **IMT for 2020** 5G mobile broadband connected society. The technical standards for IMT-2020 will be finalized by ITU–R in 2020. While enhancing mobile broadband communications, 5G will also extend the application of this technology to use cases involving ultra-reliable and low latency communications, and massive machine-type communications. In addition, the ITU World Radiocommunication Conference 2019 (**WRC-19**) will address the need to identify additional spectrum to support the future growth of IMT.

Mobile devices typically contain multiple antennas and associated radio frequency front ends to enable operation in multiple bands to facilitate roaming. While mobile devices can benefit from common chipsets, variances in frequency arrangements necessitate different components to accommodate these differences, which leads to higher equipment design complexity and cost.

Consequently, harmonization of spectrum for IMT leads to simplification and commonality of equipment, which is desirable for achieving economies of scale and affordability of equipment.

As mentioned previously, it was by a decision at the 1992 World Administrative Radiocommunication Conference (WARC-92) that the first specific frequency bands for the operation of FPLMTS (now IMT) were identified in the ITU Radio Regulations, the international treaty governing the use of the radio frequency spectrum and satellite orbits. Identification of a frequency band in the Radio Regulations does not afford any priority for such use with respect to other radio services allocated to that spectrum, but it does provide a clear signal to the national regulators for their spectrum planning, and also provides a degree of confidence for equipment manufacturers and network operators to make the long-term investments necessary to develop IMT in these bands.

No single frequency range satisfies all the criteria required to deploy IMT systems, particularly in countries with diverse geographic and population density; therefore, to meet the capacity and coverage requirements of IMT systems, multiple frequency ranges are needed.

Since WARC-92, successive World Radiocommunication Conferences, in 1997, 2000, 2007 and 2015, have periodically identified additional frequency bands for IMT within the range of 450 MHz to 6 GHz to cater for the rapidly growing demand for mobile communications, particularly mobile broadband data.

While the 2015 World Radiocommunication Conference made good progress in identifying additional frequency bands and globally harmonized arrangements below 6 GHz for the operation of IMT, it also recognized a potential future requirement for large contiguous blocks of spectrum at higher frequencies for these systems. Consequently, it called for 11 frequency bands within the range 24 GHz–86 GHz to be studied by ITU–R as bands that may be identified for use by IMT at the World Radiocommunication Conference in 2019 (WRC-19). The focus of these studies is to identify a limited subset of these bands that are recommended to be identified globally for use by IMT.

Conclusion

The scope of 5G is much broader than the previous generations of mobile broadband communication systems. We are talking here about not just an enhancement to the traditional mobile broadband scenarios, but extending them to use cases involving ultra-reliable and low latency communications, and massive machine-type communications. ITU's work in developing the standards for IMT-2020, in close collaboration with the whole range of 5G stakeholders, is now well underway, along with the associated spectrum management and spectrum identification aspects.

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Forging paths to IMT-2020 (5G)

Stephen M. Blust
Chairman, ITU Radiocommunication Sector (ITU–R) **Working Party 5D**

Sergio Buonomo
Counsellor, ITU–R **Study Group 5**

Work on International Mobile Telecommunications (IMT) has been happening for over three decades in ITU. This has been an open process which has included ITU's Member States, national and regional standards development organizations, equipment manufacturers, network operators, as well as academia and industry forums. There is no doubt that this activity has revolutionized the way people communicate around the world.

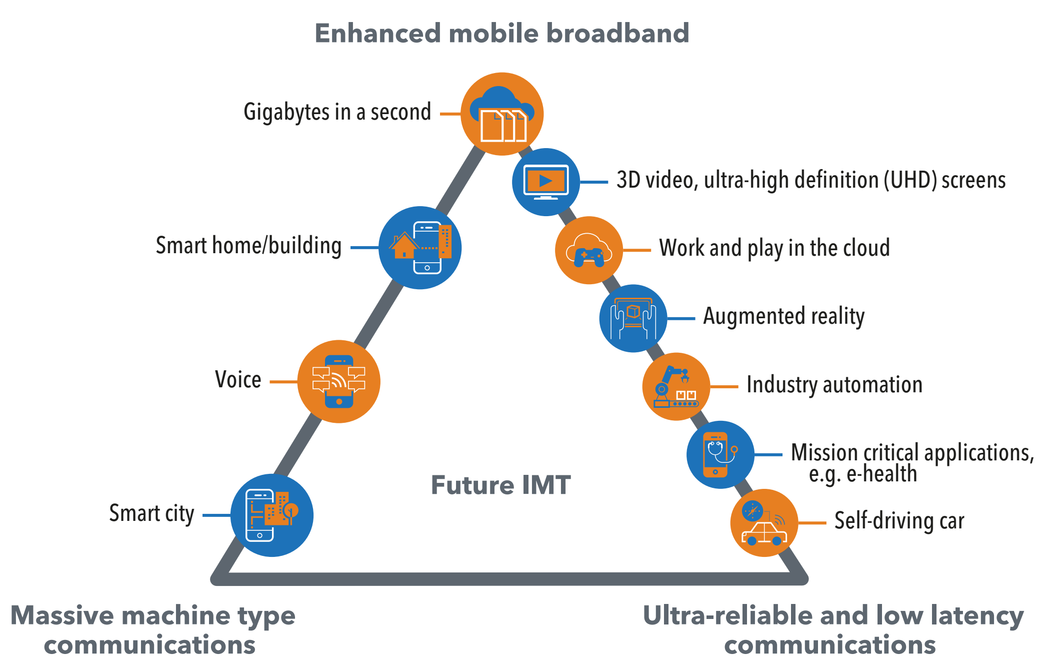
IMT is increasingly becoming the primary means for accessing communication, information, and entertainment.

Nowadays, 3G and 4G mobile broadband systems are based on the ITU's IMT standards. Detailed specifications for **IMT-2000** (3G) have been in force since the year 2000, and the **IMT-Advanced** (4G/LTE) specifications were approved by the ITU Radiocommunication Sector (ITU–R) **Radiocommunication Assembly** in 2012 (**RA-12**).

The next step is the development of a complete specification for 5G (under the ITU name **IMT-2020**) to support the next generations of broadband and Internet-of-Things (IoT) connectivity. This is planned to be finalized in year 2020.

5G technologies will further enrich the global communications ecosystem for enhanced mobile-broadband communications, expanding the range of possible applications through further advances in high data rate communications on the one hand, and on the other hand, the ability to also accommodate the gamut of IoT devices. This will be achieved by adopting new, more efficient and effective radiocommunications techniques and system architectures over a wide range of radio spectrum, ranging from the traditional mobile communications bands into the emerging so-called "millimeter wave" radio bands in the region above 6 GHz.

5G usage scenarios from the ITU–R IMT-2020 Vision Recommendation



What does IMT have to offer?

In this context, IMT will offer high-reliability communication supporting very low latency, enhanced multimedia services, including ultra-high definition video, extraordinary quality at speeds from stationary to high mobility, coupled with the addition of mission-critical communications capabilities, and support for the burgeoning Internet of Things.

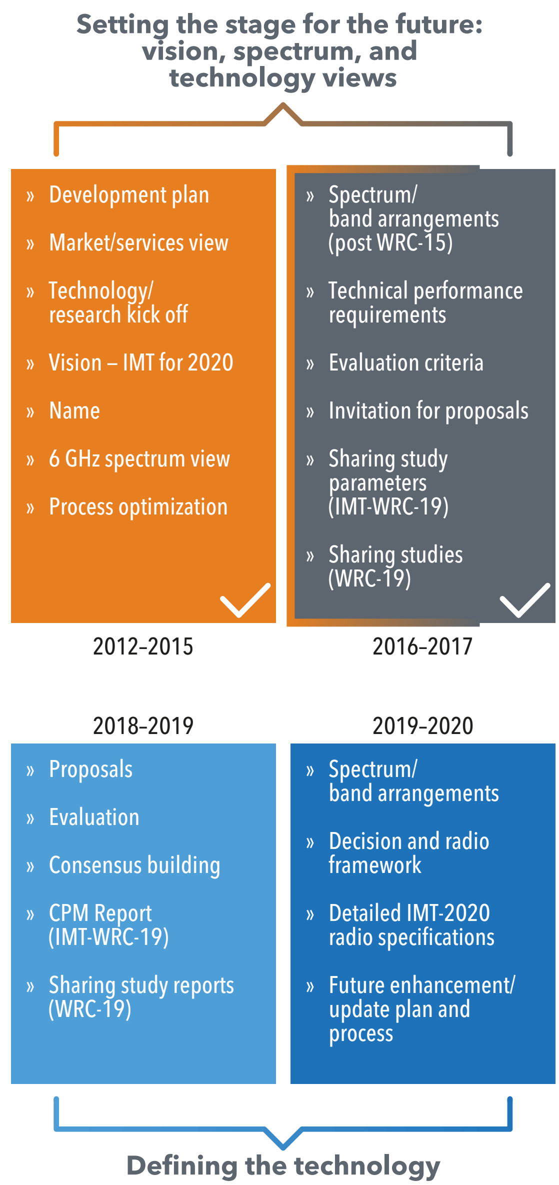
ITU, as a strategic planner, is looking toward the longer-term future. Already in 2011, it undertook pre-cursor work to stimulate future thinking by organizing regional workshops – "IMT for the next decade". In 2015, the critical future IMT vision Recommendation as well as material outlining the technology underpinnings was released. Now, work is underway for the next step: defining the technology.

How 5G will be different

Compared to previous generations, 5G will be different because of the new and enhanced capabilities needed to enable the wide range of use cases envisaged. This translates into a demanding and far-reaching set of technical requirements that takes us well beyond where we are today in the systems, networks and radio capabilities. We really are looking at a clean-slate approach, learning from the last 20 years of technology evolution, to realize this vision.

ITU issued the invitation for submission of proposals for candidate radio interface technologies for the terrestrial components of the radio interface(s) for IMT-2020 and an invitation to participate in their subsequent evaluation in Circular Letter **5/LCCE/59** on 22 March 2016.

IMT-2020 standardization process



The next phase – finalizing IMT performance requirements

In the next phase, during 2017, ITU–R Working Party 5D (the group responsible for IMT systems) will finalize the performance requirements, evaluation criteria and methodology for the assessment of new IMT radio interface.

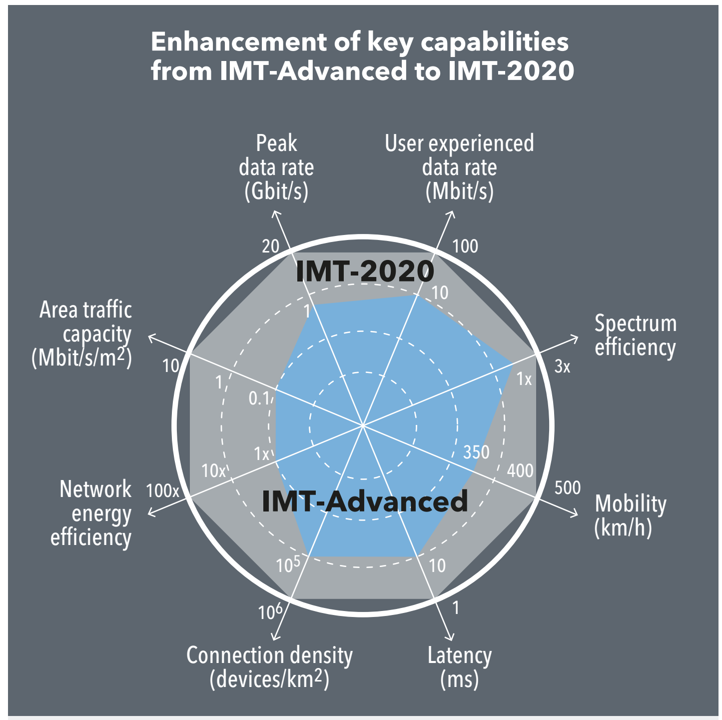
In addition, ITU–R will address matters associated with spectrum related to IMT both for radio bands already identified for operation of IMT, and for bands that are under consideration for future use. The whole process is planned to be completed in 2020, when an ITU–R Recommendation containing the detailed specifications of IMT-2020 will be issued.

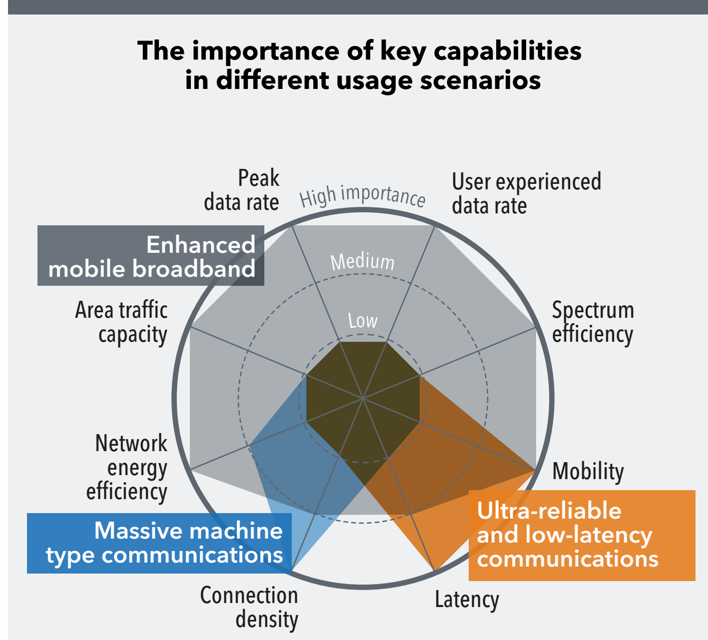
The submission of proposals is expected to begin in October 2017 and end by mid-2019. The evaluations against the criteria will then be carried out by Working Party 5D, assisted by independent evaluation groups established for this purpose, and participation in these groups is not limited to ITU members.

It is important to stress that the development of IMT standards is not carried out by ITU alone. It is a highly collaborative process with substantial input from and coordination with ITU Member States, equipment manufacturers, network operators, and all involved national, regional and international standards development organizations, partnerships and fora.

The evaluation reports from the evaluation groups are presented and considered in Working Party 5D and form a basis for developing consensus on which proposed interfaces should be included in the IMT-2020 standard.

5G capability perspectives from the ITU–R IMT-2020 Vision Recommendation





The values in the figures above are targets for research and investigation for IMT-2020 and may be revised in the light of future studies. Further information is available in the IMT-2020 Vision (Recommendation ITU-R M.2083)

Recognizing future requirements for spectrum

On the spectrum side, while the 2015 World Radiocommunication Conference (**WRC-15**) made good progress in identifying additional frequency bands and globally harmonized arrangements below 6 GHz for the operation of IMT, it also recognized the potential future requirement for large contiguous blocks of spectrum for this application.

Consequently, WRC-15 called for 11 frequency bands above 24 GHz to be studied by ITU–R as bands that may be identified for future use by IMT at the next World Radiocommunication Conference in 2019 (**WRC-19**).

As a parallel activity, the bands considered as suitable for IMT operation need to be identified and sharing studies associated with the use of these bands need to be conducted in preparation for WRC-19, and these decisions regarding spectrum use will need to be taken into account in developing the final IMT-2020 specifications.

Anticipating IMT-2020 technical trials

In the coming years we can anticipate early technical trials, market trials and deployments of 5G technologies based on the foreseen developments slated for IMT-2020.

These systems may not provide the full set of capabilities envisaged for IMT-2020, but the results of these early trials will flow forward into and assist the development of the final complete detailed specifications for IMT-2020.

IMT is the ongoing enabler of new trends in communication devices — from the connected car and intelligent transport systems to augmented reality, holography, and wearable devices, and a key enabler to meet social needs in the areas of mobile education, connected health and emergency telecommunications. E-applications are transforming the way we do business and govern our countries, and smart cities are pointing the way to cleaner, safer, more comfortable lives in our urban conglomerates. Certainly, IMT-2020 will be a global cornerstone for all of the activities related to broadband communications and IoT for the future — enriching lives in ways yet to be imagined as we move into the world beyond 2020.

A new age of orchestration for 5G

Chaesub Lee

Director, **ITU Telecommunication Standardization Bureau**

As we approach 2020, one of the most important areas of ITU's work will be our international standardization of 5G systems.

ITU is supporting the development of a 5G environment where we will all have access to highly reliable communications, and where trusted information and communication technologies (ICTs) will be key to innovation in every industry sector.

As we approach 2020, one of the most important areas of ITU's work will be our international standardization of 5G systems.

Chaesub Lee

5G networks will be highly agile, orchestrated, all-around players

In 2012, ITU established a programme on "International Mobile Telecommunications for 2020 and Beyond (IMT-2020)", providing the framework for 5G research and development worldwide.

ITU has defined the framework and overall objectives of the 5G standardization process, as well as the roadmap to guide this process to its conclusion by 2020.

"IMT Vision", published in September 2015 as Recommendation ITU-R **M.2083**, put forward an initial set of 5G performance targets, which have now been elaborated more precisely in a draft report providing "**Minimum requirements related to technical performance for IMT-2020 radio interface(s)**". This draft report is on course for final approval in November 2017.

These two documents make for very informative reading. Alongside enhanced mobile broadband and the Internet of Things, 5G will support ultra-reliable and low-latency communications for applications such as automated driving, remote medical surgery, collaborative robotics, and advanced virtual reality. At this high end of 5G applications, in some cases we will demand end-to-end latencies as low as 1 millisecond.

What becomes evident when looking at the ambitious performance targets of 5G systems, and the wide variety of envisioned 5G applications, is that future networks will need to be agile all-around players able to perform a wide array of specialized functions.

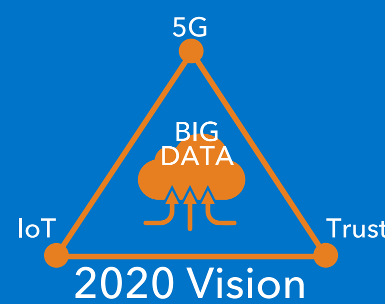
5G will make no compromises when it comes to performance

Engineers are developing specialized air interfaces, and specialized networks to support those air interfaces, to ensure that every application is able to perform to its full potential. As work has progressed on 5G air interfaces, it has become abundantly clear that today's network architectures and orchestration techniques simply cannot support the performance targets of 5G systems.

In May 2015, ITU established a Focus Group on the network aspects of IMT-2020 to address exactly this challenge.

2020 vision and beyond

ITU-T aims to provide members with a standardization toolkit optimized to assist government and industry in achieving their ambitions for the year 2020 and beyond. The future of standardization will be driven by 5G, IoT and Trust as enablers supporting the UN Sustainable Development Goals.



Real-time standardization

Over 300 new ITU standards released each year

Market-driven standards

Over 4000 active standards in use

The Focus Group explored how emerging 5G technologies will interact in future networks, studying network softwarization and slicing, 5G architecture and fixed-mobile convergence, end-to-end network management, information-centric networking (ICN), and related open-source innovation.

This group met the high expectations of the ITU membership, concluding its study with the delivery of five draft ITU standards and four draft ITU technical papers to fuel standardization work led by the ITU Standardization Sector (ITU–T) Study Group 13. Learn more about the **Focus Group's output**.

The Focus Group's final meeting in December 2016 also hosted a "workshop and demo day" showcasing proofs of concept and demonstrations of the wireline technologies to enable future 5G systems. Learn more about the **5G demos**.

Softwarization and slicing is leading orchestration into a new era

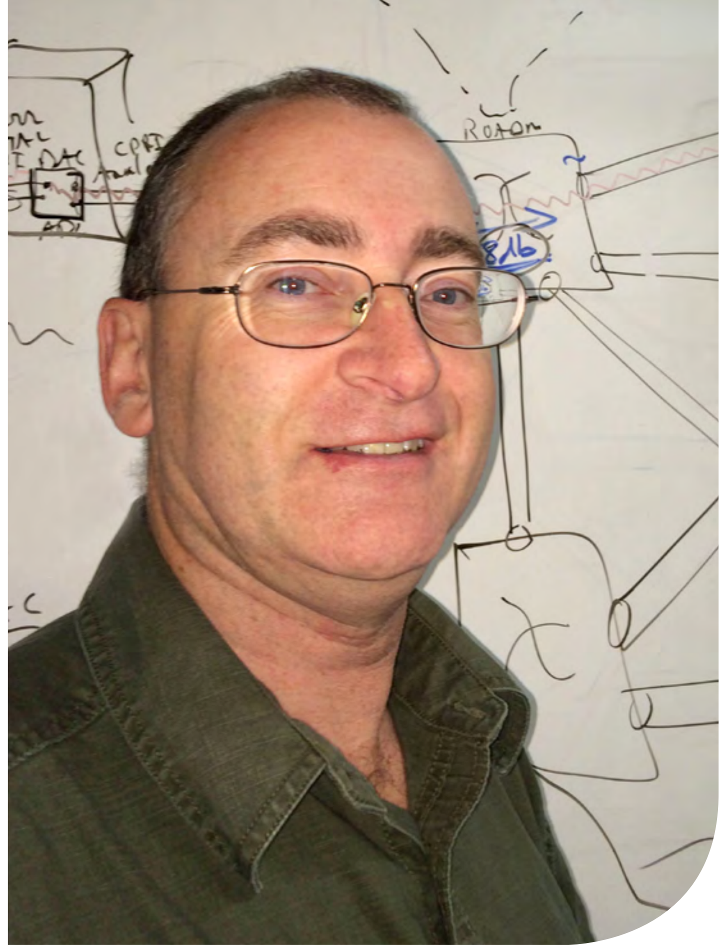
Softwarization, a concept rooted in data center networking, is a movement toward automating and adding intelligence to processes once carried out manually. The concept is at the heart of networking innovation for 5G, with 5G expected to depend heavily on cloud and very modern computing, transportation, and data center technologies.

The Focus Group's work made it clear that network softwarization and slicing, underpinning deeply programmable networks able to be "sliced" into virtual networks with very specialized capabilities, will be fundamental to the dynamic allocation of network resources in the 5G environment, giving networks the agility required to support the specific requirements of any particular 5G application.

Telcos know softwarization to be central to the future of network orchestration, and they are fast adopting this way of working, learning from data center and cloud specialists such as Facebook, Google, and Netflix. Softwarization is already making an entrance into telco operations, with examples found in network function virtualization and software-defined networking. As we see 5G networks beginning to take shape, telcos will continue to develop their softwarization and cloud-computing capabilities, with much of this work driven by open-source innovation.

The Focus Group studied the end-to-end softwarization of all the major components of the 5G network, from mobile devices to antennas, to the data center and cloud, and perhaps one of the most important outputs of the Focus Group was its description of softwarization as it cuts through all of these layers.

To follow ITU's progress in standardizing 5G air interfaces, stay tuned in to the IMT-2020 standardization process coordinated by the ITU Radiocommunication Sector (ITU–R) **Working Party 5D** (IMT systems). To follow ITU's progress in supporting the wireline networking innovation necessary to 5G, keep an eye on the work of **ITU–T Study Group 13** (Future networks) and **ITU–T Study Group 15** (Transport, Access and Home).



Why end-to-end network slicing will be important for 5G

Peter Ashwood-Smith

ITU–T IMT-2020 Focus Group Chair
5G Network Research Director, **Huawei**

If you have been following developments in telecommunications in the last year or so you have no doubt heard the term "slicing" as it pertains to future 5G networks. This short article will hopefully give you a high-level view of what "slicing" is, why it's important for 5G systems, and some indication of the work accomplished by the ITU Telecommunication Standardization Sector (**ITU–T**) on this important new technology.

The need for slicing future network systems can perhaps best be understood by looking at city transportation systems. In a city, we don't provide a single transportation mechanism. Instead, the infrastructure of the city is divided – *sliced*, if you will – into areas for cars, buses, subways, etc.

Some of the infrastructure is dedicated to a particular form of transportation (eg. trains), while other infrastructure can share different kinds of transportation (eg. roads are shared by cars as well as buses, which may have priority lanes).

> ***"Much of the challenge with 5G will be providing the proper degree of orchestration that ensures harmonious end-to-end operation."***
>
> Peter Ashwood-Smith

This analogy mirrors nicely what we plan to do with 5G. Essentially, we intend to take the infrastructure resources from the spectrum, antennas and all of the backend network and equipment and use it to create multiple sub-networks with different properties.

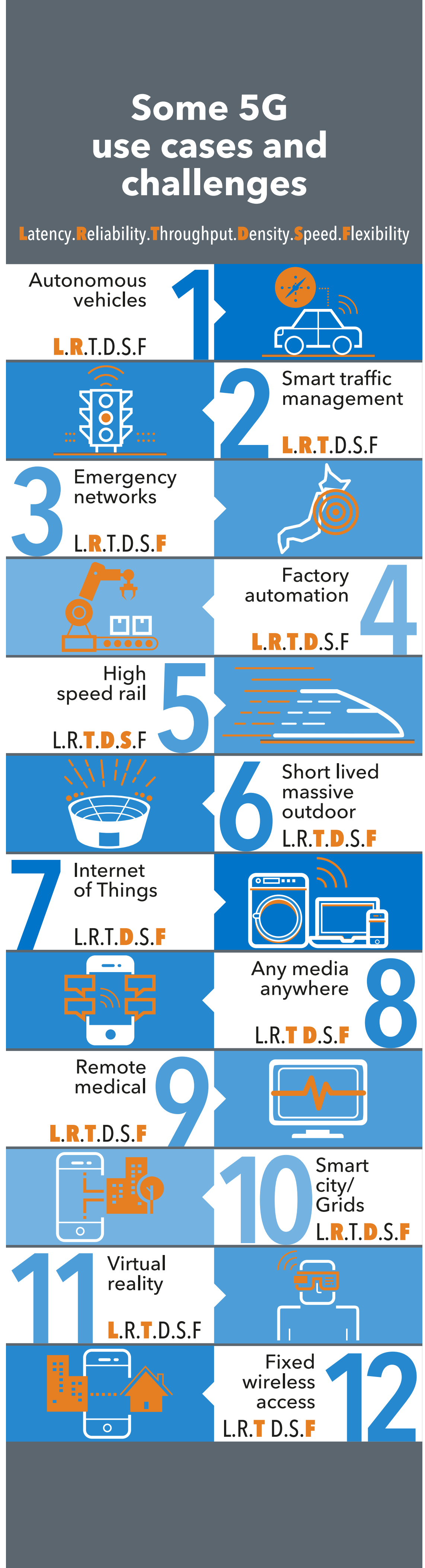
Each sub-network *slices* the resources from the physical network, end to end, to create its own independent, no-compromise network for its preferred applications.

Next-generation network challenges

In today's Internet-of-Things (IoT) era, we are creating new types of machines, both big and small, at an amazing rate. Connecting these machines offers great opportunity, but brings with it a host of challenges.

Today's 3G/4G/LTE networks do a wonderful job connecting people, but they pose a number of problems when used to connect machines. This is because the 3G/4G/LTE networks were designed as a set of compromises.

For example, the 4G/LTE networks do not give the lowest possible delay because to do so would have an adverse effect on the bandwidth they could provide. Likewise, the careful scheduling of individual users through multiple message exchanges creates higher throughput and more fair access, however, it uses considerable battery resources in the handsets to do so. Some of the challenges for next-generation applications and the current situation with 4G are depicted in the figure.



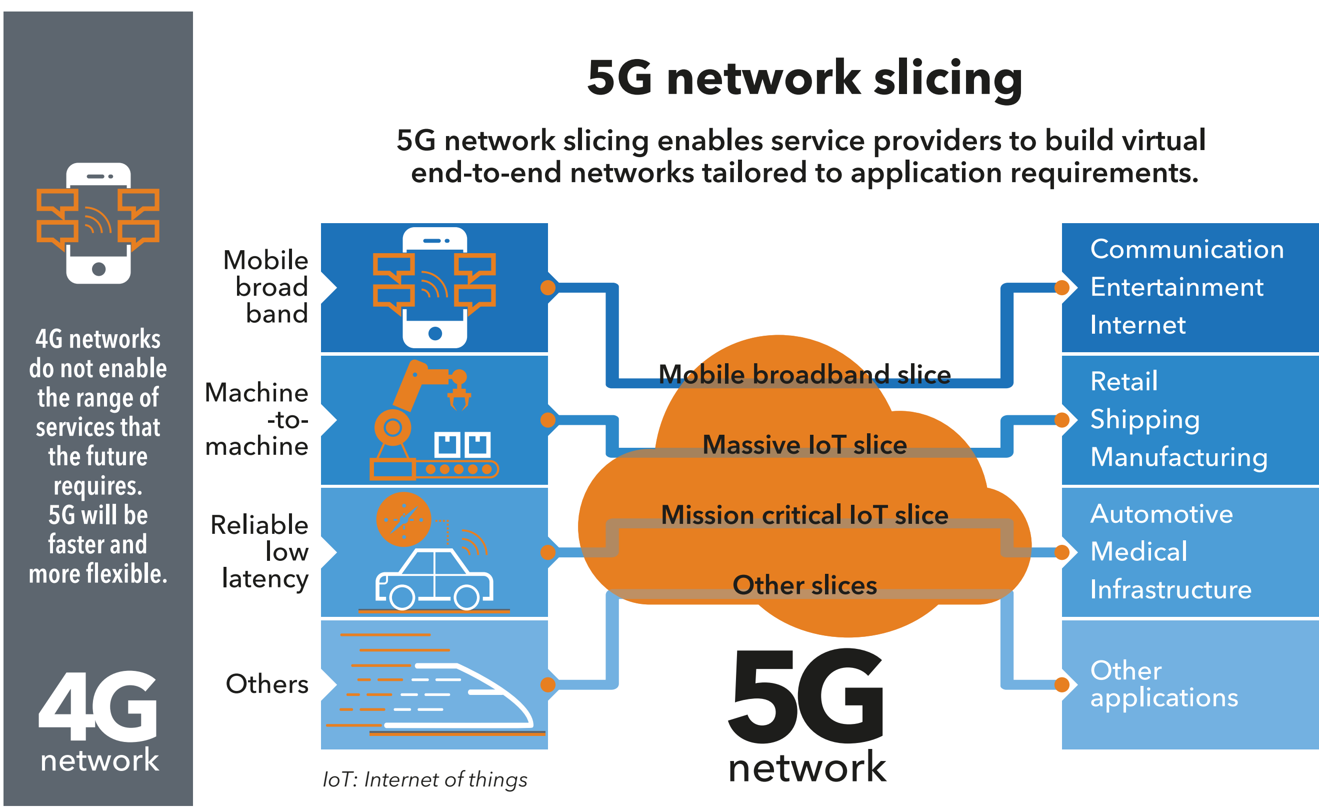
Slice types

To address the different needs of different types of machines and devices, the interface between the device and the antennas (the air interface) will have several different specialized/tailored behaviours. These are referred to as *slice types*.

One *slice type* is specifically targeted for ultra-low latency and high reliability (like self-driving vehicles) (URRLC), another *slice type* is specifically targeted for devices that don't have large batteries (like sensors) (MMTC) and need efficiency and yet another *slice type* is targeted at ultra-high speed (eMBB) as required for 4K or immersive 3d video. While the initial standards work calls for only three *slice types*, the architectures are flexible for future *slice types*.

Since it would be far too expensive to allocate a complete end-to-end network to each type of slice, the network infrastructure that supports 5G (and likely 4G) will employ sharing techniques (virtualization and cloud), which allow for multiple *slice types* to co-exist without having too many multiples of the resources.

Cloud and packet-based statistical multiplexing techniques are employed to allow the slices to use each other's resources when they are free. In this manner N-network slices can be implemented with far less than N x the number of resources. This is depicted in the figure.



IoT: Internet of things

In order to make such networks a reality all the components need to work properly in harmony. Much of the challenge with 5G will be providing the proper degree of orchestration that ensures harmonious end-to-end operation, and as a result, this is one of many areas under study by ITU–T.

ITU–T — researching standards for 5G

ITU–T's Study Group 13 (SG13) recently created a Focus Group with a mandate to research the areas that needed standardization for the non-radio aspects of 5G. The harmonious operation through software control, referred to as "softwarization" of all of the components of the 5G network, was one of the many subjects studied by the Focus Group, and which is now being more formally considered by **SG13**. Many of the areas requiring control are not uniquely wireless components but are also involved in service providers' other end-to-end-businesses.

For example, the cloud and transport networks which interconnect them will require new agile control to ensure that the packet, non-packet interconnections and compute, meet the Quality-of-Service (QoS) demands of that slice.

The success of 5G lies in entire ecosystems

5G slicing technology, to be truly successful, will need entire ecosystems to come together to solve and standardize their end-to-end applications.

As a result we fully expect to see the automotive, health care, agricultural, manufacturing etc. ecosystems to become more and more involved in 5G and to help drive the potential that slicing can provide.

Key to 5G networks: leveraging Information-Centric Networking (ICN)

Giovanna Carofiglio

Distinguished Engineer, **Cisco Systems**

The fifth generation of cellular networking is not just about a new radio, it is also about building a transformative network architecture to simplify, automate and virtualize delivery of a very diverse set of services over mobile heterogeneous access.

Video, in all its new and bandwidth-hungry forms, such as VR (Virtual Reality) and AR (Augmented Reality), is clearly a source of massive network traffic, especially in the mobile network. This results in significant pressure on the network to sustain ever-growing mobile and multi-access video delivery under different formats, bitrates, and security profiles, which calls for information awareness at every level of the network stack.

Beyond video, many of the ambitious 5G use cases require a more powerful data forwarding plane, which would include better support for heterogeneous networks (access networks and whole network deployments), multi-path communication, in-network storage, and implementation of operator policies.

> *"ICN adoption may dramatically simplify next-generation network architecture."*
>
> Giovanna Carofiglio

This would help to avoid overlay silos, and would simplify network management.

Leveraging ICN for 5G

Cisco believes the answer is a richer content-aware network leveraging the Information-Centric Networking (ICN) concept. ICN is an approach to evolve the Internet infrastructure to directly support data-centric and location independent communications by introducing named data as a core Internet principle.

With ICN, data access becomes independent from location; enabling a more flexible, secure and efficient communication model. It has the potential to address many of the key problems faced by the Internet today, including content distribution, **mobility**, **security**, and scalability.

ICN technology was developed at PARC, a Xerox company, a decade ago, under the name "Content-Centric Networking" (CCN). Cisco has been working with PARC and other organizations in industry, government and academia for almost a decade to create and improve CCN and has recently announced its **acquisition of the CCN platform** from PARC, as an important milestone in the path of deployment of Information-Centric Networking technology in 5G mobile networks. Cisco's recent acquisition of PARC's CCN will foster convergence of various dialects of ICN (CCN and NDN) into a single harmonized version of ICN, promoting wider and faster adoption of ICN-based solutions required to solve future networking needs.

Learn more about CISCO's ICN ***5G*** *vision by watching this* ***video*** *demonstration.*

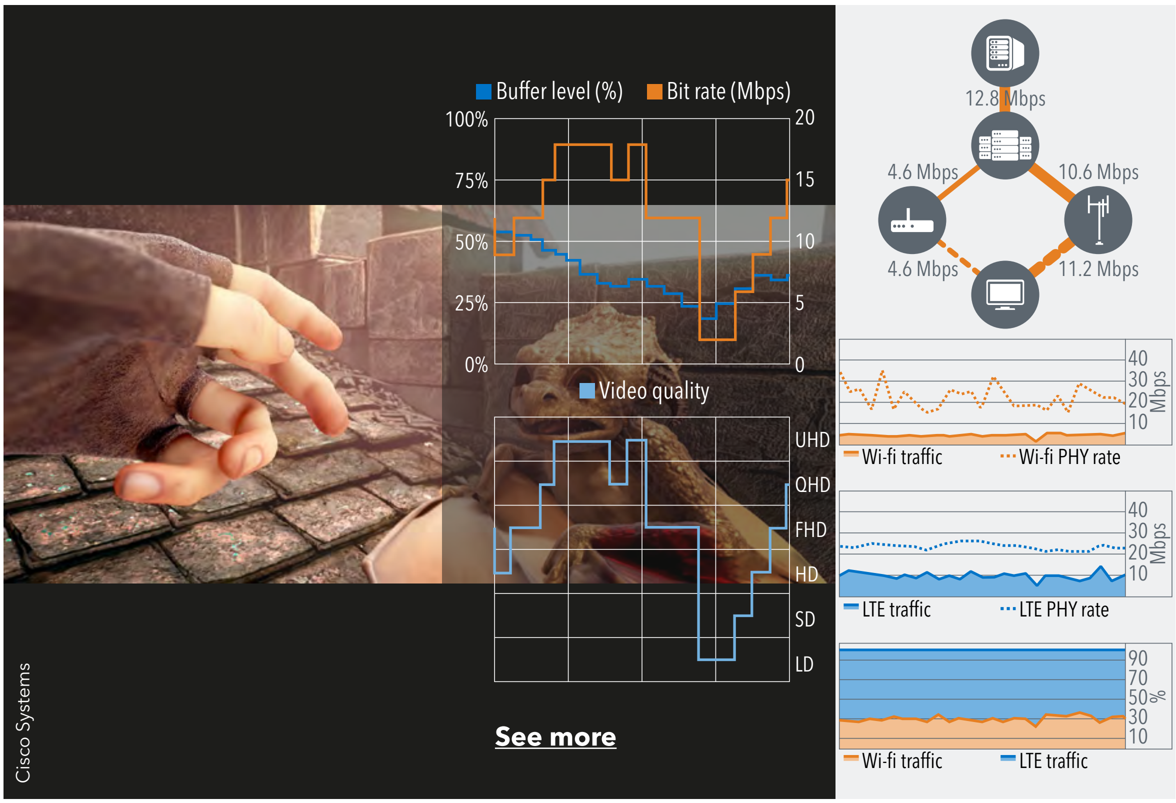
Open-source ICN

Toward the same end, we recently announced the creation of CISCO's open-source project called Community ICN (CICN), within the Linux Foundation's **FD.IO community**.

Cisco will be contributing its own ICN software, including the CCN software acquired from PARC, to this open-source project. The open-source initiative is intended to accelerate ICN development by means of community contribution at large, and to guarantee continued support.

While contributing to ICN standardization and adoption, we at Cisco have worked on strategies to accelerate ICN insertion in 5G and facilitate incremental deployment into existing Internet Protocol (IP) infrastructure.

Mobile Video Delivery with Hybrid ICN
IP-integrated ICN solution for 5G



Hybrid ICN

We have recently disclosed our hybrid solution: **Hybrid ICN (hICN)** – which enables the deployment of ICN within IP – rather than as an overlay or replacement of IP. It preserves all features of ICN communication by encoding ICN names into IP addresses.

Key features of hICN are that it supports IPv4 or IPv6 RFC compliant packet formats, and guarantees transparent interconnection with standard IP networking equipment, simplifying the insertion of ICN technology in existing IP infrastructure and enabling coexistence with legacy IP traffic.

Recognized as an emerging innovative technology for 5G, ICN adoption may dramatically simplify next-generation network architecture by offering a unified, content-aware and access-agnostic network substrate for the integration of 5G heterogeneous networks.

Opening up 5G

Marc Cohn

Vice President of Network Strategy
The **Linux Foundation**

The next mobile generation (5G) is not just redefining mobile services – it is also ushering in an era of open technologies that are transforming the telecommunications industry.

Software-defined networking (SDN) and network functions virtualization (NFV) represent the future in telecommunications, by virtualizing the infrastructure and services to offer unprecedented agility, intelligence, and openness.

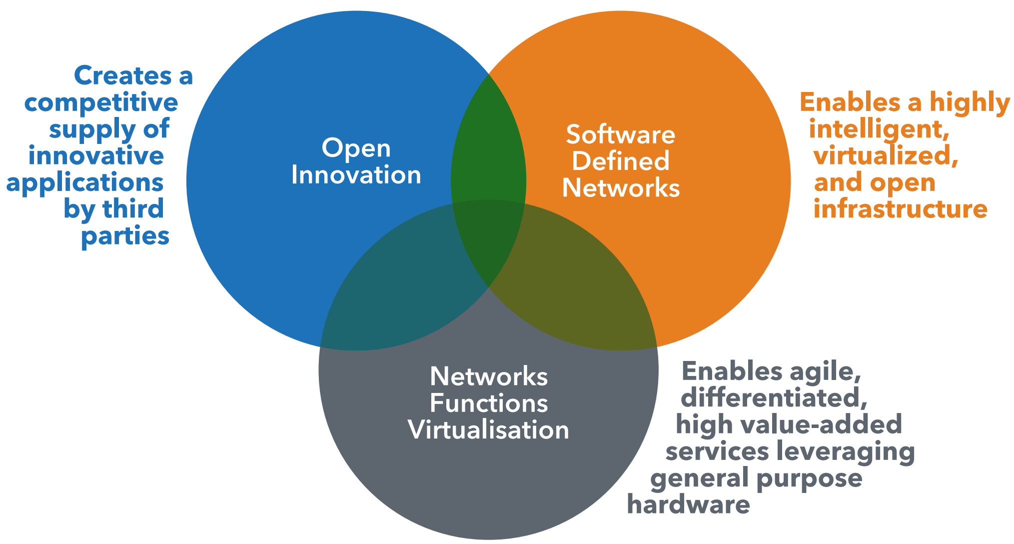
For the past five years, SDN and NFV have been progressing due to unique collaboration between standards organizations and open-source communities that together are reshaping how new technology may be adopted.

Innovative industry groups such as the **ETSI NFV ISG** and the **Open Networking Foundation** established the reference architectures, validated use cases, and reshaped the requirements for open-source building blocks integral to NFV and SDN.

"5G is not just redefining mobile services – it is also ushering in an era of open technologies that are transforming the telecommunications industry."

Marc Cohn

What's in an NFV Cloud?



Large-scale, open-source networking

In response, in 2012, The Linux Foundation introduced the first large-scale, open-source networking platform, **OpenDaylight**. The open SDN Controller Framework has since established a broad technical community; over 900 developers contributed to the current release. OpenDaylight has spawned commercial offerings supporting hundreds of millions of subscribers around the globe.

SDN and NFV have emerged as critical technologies for 5G to enable a wide range of data-driven applications that have been written about extensively on OpenDaylight, including mobile broadband, the Internet of Things (IoT), mobile-to-mobile (M2M), etc.

To enable such a diverse range of end-user applications, the SDN/NFV management and control model must become much more highly scalable, intelligent, flexible, and open than ever before.

Many of the telecommunications industry's most innovative and proactive operators and solution providers have undertaken the challenge to redefine the service delivery lifecycle as a result. This requires unique collaboration among the network management standards bodies, SDN/NFV industry organizations, and the open source community.


Linux Foundation

Over the past year, there has been a number of open-source initiatives announced to address the challenges of network orchestration and automation, including the ETSI Open Source MANO (**OSM**) project, Linux Foundation **OPEN-O** project, AT&T's open source **ECOMP** (Enhanced Control, Orchestration, Management, and Policy) project (also with The Linux Foundation), among others.

Groundbreaking collaboration with ONAP

While having multiple alternatives offers the potential for competing approaches that the market will select based on their individual innovations and merits, the potential for fragmentation and dilution of investment looms. That is why the principals in the OPEN-O and open-source ECOMP communities announced a groundbreaking effort to converge, resulting in the introduction of the Open Network Automation Platform (**ONAP**), under The Linux Foundation.

On Day 1, ONAP founding members represented just under 40% of the world's mobile subscribers, and virtually all of the leading solution providers. Such critical mass is essential, considering the need to forge a common, industry-wide, open platform for service automation and orchestration.

ONAP intends to address the entire service-delivery lifecycle, including:

- Service Design – A model-driven approach that minimizes software development for new and derivative services.
- OSS/BSS/UI Integration – Open orchestration raises an industry debate about which OSS functions will be captured in the platform, versus existing back-end approaches.
- Virtualized Network Function (VNF) Orchestration – VNFs represent the building blocks for composite services; ONAP is participating in an industry-wide effort to streamline VNF onboarding, establishing a common packaging format to enable many to participate in the emerging open SDN/NFV ecosystem.

- Connectivity Services Orchestration – For end-to-end service delivery, a flexible set of capabilities are needed to achieve orchestration across a wide range of network domains and technologies.
- Service Management – Rounding out the platform includes a rich set of policy management, analytics, and related functions to enable a more intelligent service delivery lifecycle.

The ONAP project leverages The Linux Foundation's best practices refined by over 25 years of enabling some of the world's most important open-source projects. ONAP is a truly global project, featuring an open governance model forum to discuss architecture initiatives. It makes for a healthy blend between operators and vendors and top-down/bottom-up decision making.

The project was announced in February 2017, and is currently in the process of release planning and initial ramp-up.

As 5G rapidly approaches reality, it is imperative for standards bodies, industry groups, and the open-source community to undertake a highly collaborative approach for a pragmatic technology adoption lifecycle for SDN/NFV. By working together, use cases may be prioritized to guide development, requirements and implementation may be validated and the many tradeoffs that arise may be thoroughly considered.

"Software Defined Networking (SDN) and Network Functions Virtualization (NFV) represent the future in telecommunications."

Marc Cohn

Working in a neutral and open forum, an inclusive and open community will catalyze the cultivation of the open ecosystem that enables many to benefit.

The future of telecommunications is currently being reshaped by SDN/NFV, with 5G among the first projects to realize the vision of a truly converged, next-generation mobile infrastructure.

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