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Terrestrial wireless communications

Identifying, managing and harmonizing radio-frequency spectrum

Enabling terrestrial wireless communications

Houlin Zhao

ITU Secretary-General

Wireless communications have helped connect billions of people to the Internet so that they can reap the benefits of today's digital economy.

Nearly every sector of the economy now relies upon wireless technologies – from banking and agriculture to transportation and health care. And powerful new technologies that rely on robust wireless communications networks – such as 5G, Artificial Intelligence and Internet of Things – hold great promise to improve lives at an unprecedented pace and scale.

Indeed, they have potential to accelerate progress towards achieving each of the 17 United Nations Sustainable Development Goals (SDGs).

ITU's Radiocommunication Sector (ITU–R) globally regulates the use of radio-frequency spectrum and satellite orbits to ensure these critical resources are used rationally, efficiently, economically, and equitably, and to prevent harmful interference between services of different government administrations.

In October, ITU's World Radiocommunication Conference 2019 (WRC-19) will update the very important Radio Regulations international treaty, enabling those industries that are using current and future terrestrial radiocommunication technologies to continue to bring benefits to everyone.

In this edition of the ITU News Magazine you will learn more about the importance of terrestrial wireless communications and how WRC-19 can enable their continued success and rollout.

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Contents

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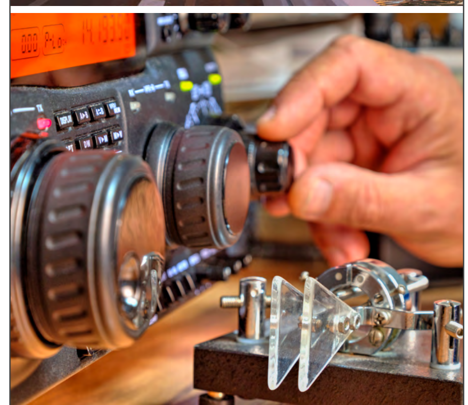
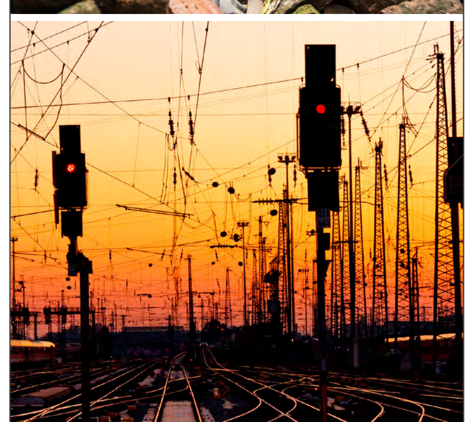
Contents





The importance of terrestrial wireless communications

Mario Maniewicz

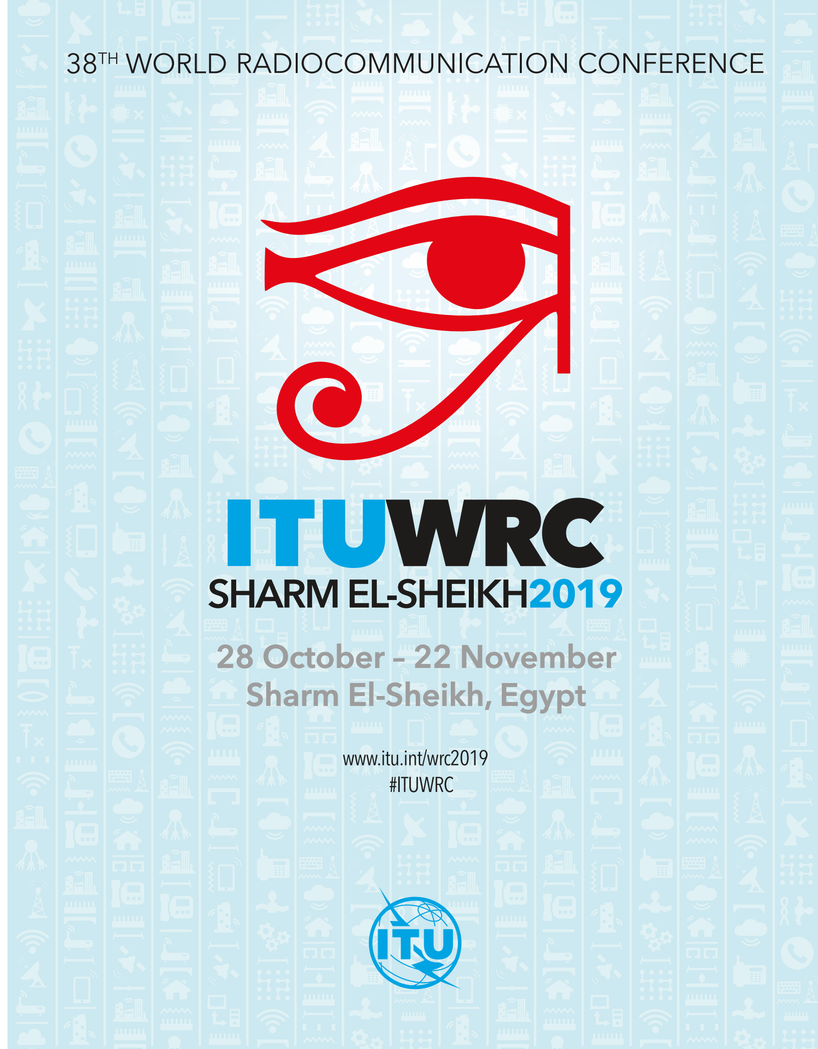
Director of the ITU Radiocommunication Bureau

Wireless devices are notably visible and extremely present in our everyday lives. Smartphones and tablets with embedded Wi-Fi accompany people almost everywhere. We listen to the radio in our cars, watch free-to-air television programmes at home, travel safely in cities and around the globe, staying connected, thanks to terrestrial wireless communication systems.

Consumer demand for wireless services has increased exponentially in recent years, leading to an explosive growth of networks and devices and bringing great benefits for economies. According to ITU, active mobile broadband subscriptions reached 4.69 billion in 2017. In 2018, according to GSMA, the mobile industry made a total contribution of USD 3.9 trillion of economic value, equivalent to 4.6 per cent of global GDP. The Internet of Things (IoT) market is also growing very fast, with currently around 7 billion devices, according to data from IoT Analytics.

"Wireless devices are notably visible and extremely present in our everyday lives."

Mario Maniewicz



To adequately satisfy consumer demand, terrestrial radio technologies have evolved considerably over the past few decades, and new applications have emerged. They include advanced mobile broadband, intelligent transport systems and IoT devices. Frequencies and regulations for these technologies are on the agenda of the World Radiocommunication Conference (WRC-19) to be held in Sharm el-Sheikh, Egypt, in November 2019.

Amateur radio

The amateur radio service was born more than 100 years ago and continues to be very valuable, bringing young people into a fascinating world of radio. A great variety of modern radio technologies have been developed and tested by radio amateurs. Today, the number of radio amateurs reaches 3 million, and national amateur radio societies operate in 167 countries, according to IARU. At WRC-19 the amateur community targets worldwide harmonization of the 50–54 MHz band to ensure reliable, middle-range communications everywhere in the world.

IMT-2020 (5G) — enhanced broadband and beyond

One of the most challenging WRC-19 issues is the spectrum and regulations for the next generation of International Mobile Telecommunications (IMT-2020 or 5G) in the millimeter bands. These bands above 24 GHz, having a huge capacity, are needed to enable superfast data rates and empower new services such as 3D video, augmented, virtual reality and others.

5G represents an evolution of IMT-Advanced/4G systems. These 4G systems have opened a new era for mobile Internet, serve a basis of many apps-based businesses, used for such services as m-Learning, m-Health, mobile money. They have become a powerful and reliable platform for broadband services — especially in developing countries — for bridging the digital divide.

IMT-2020/5G is also seen as the first mobile platform that supports not only mobile broadband, but a variety of applications, such as massive machine-type communications, autonomous cars, public safety, etc. Its characteristics could meet the communication requirements of transport, manufacturing, the health sector and other industries.

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ITU's contribution to 5G includes harmonized frequency bands and IMT-2020 standards to allow for a commercial IMT-2020/5G deployment starting from 2020.

Radio Local Area Networks (RLANs)

Wi-Fi or Radio Local Area Networks (RLANs) in ITU terminology has been widely used for Internet connectivity and data delivery. Wi-Fi has also been used for offloading mobile traffic, thus reducing the amount of data carried on cellular networks.

The traditional 2.4 GHz and 5 GHz bands used for RLANs are heavily used and growing consumer demand requires additional capacity. WRC-19 will consider the additional spectrum needs of RLANs in their traditional 5 GHz band. This represents a challenging task due to the need for protection of several existing services.

High-altitude platform systems (HAPS)

High-altitude platform systems (HAPS) is another technology that can be used to provide broadband, directly to end users or as backhaul for stations of the mobile service. These applications would potentially enable wireless broadband in remote and rural areas. In some situations, they may be also rapidly deployed for disaster-recovery communications.

Previous WRCs have already identified frequencies in the fixed service in the 6 GHz, 27/31 GHz and 47/48 GHz bands that can be used for HAPS. However, the spectrum requirements of new broadband HAPS may not be fully accommodated within these current designations. Therefore, additional spectrum is being considered for HAPS systems in the millimetre bands above 21.4 GHz.

Intelligent transport ecosystems

Wireless technologies are changing the shape of road transport, making cars smarter, driving more convenient, and roads safer. Radiocommunications serve various aspects of transportation networks, such as vehicle navigation, traffic control, road signs and automatic licence plate recognition, etc. forming what are now referred to as Intelligent Transport Systems (ITS). A variety of technologies can contribute to ITS, including cellular networks, wireless access systems, sensors and radars.

WRC-19 will consider spectrum harmonization for ITS in different frequency bands, and particularly in the 5.8 GHz band.

Railway transportation is also an important user of radio technologies. WRC-19 will consider Railway Radiocommunication Systems between Train and Trackside (RSTT). They include wireless technologies used on-board trains, positioning information, train remote control and surveillance.

WRC-19 will determine ways of harmonizing frequency bands for these applications to improve their interoperability and reduce investments.

> "*I expect the terms* allocation, identification *and* harmonization *to be the key words of the upcoming WRC-19.*"
>
> Mario Maniewicz

Harmonization, coexistence and spectral efficiency

Finally, I would like to emphasize the important goals of the Union at WRCs: harmonization of frequency bands for wireless technologies, allocation of bands of the radio-frequency spectrum in order to avoid harmful interference between radio stations of different countries (No. 11 of the ITU Constitution), and limiting the number of frequencies and the spectrum used to the minimum essential to provide the necessary services in a satisfactory manner (No. 195 of the ITU Constitution). The importance of these objectives grows from one WRC to the next and covers an increasing number of applications.

For IMT and HAPS, intelligent transport and railway applications, amateur and RLAN harmonization, coexistence and spectral efficiency are crucial. They facilitate the deployment of regional and global networks, enable economies of scale, and make radio equipment and devices more affordable for all countries. Therefore, I expect the terms *allocation*, *identification* and *harmonization* to be the key words of the upcoming WRC-19.

ITU–R Study Group 5 – Terrestrial services

Martin Fenton

Chairman of ITU–R Study Group 5

Terrestrial radiocommunication applications are of vital importance to the global digital economy. They underpin our mobile phone networks, they support fixed and mobile Internet connectivity, and they are a key component of our global safety networks for maritime and aeronautical. They support numerous consumer devices, the needs of industry, industrial automation, Internet of Things (IoT), autonomous and connected cars, etc., etc.

Study Group 5 and its working parties play an important role in supporting all these terrestrial radiocommunication industries, both through work preparing for the various Agenda items it is responsible for, and that will be decided upon at WRC-19, and through the everyday activities of its working parties, such as capturing and promoting advances in terrestrial radiocommunication technologies (fixed, mobile, aeronautical, maritime, etc.).

The Study Group also provides technical characteristics and protection requirements for these services for use in studies right across the radiocommunications sector.

> *"Study Group 5 and its working parties play an important role in supporting all these terrestrial radiocommunication industries."*
>
> Martin Fenton

> “Standards development organizations are developing standards in line with the ITU–R vision.”
>
> Martin Fenton

The launch of 5G

The development of 5G is set to revolutionize mobile services over the next decade. 5G mobile phone services have already been launched in a number of countries including in the Republic of Korea, Switzerland, the United States and the United Kingdom. Further 5G launches are expected in the second half of 2019, and launches will accelerate in 2020.

Underpinning the development of 5G has been the work of Study Group 5 on IMT-2020. In 2015, through work in the Study Group and especially its Working Party 5D, the ITU Radiocommunication Sector (ITU–R) established the "Vision" for 5G (IMT-2020) with the publication of Recommendation ITU–R M.2083.

Looking to the global 5G standard in 2020

In 2017, we established the minimum performance requirements for 5G radio interface technologies as set out in Report ITU–R M.2410. Standards development organizations are developing standards in line with the ITU–R vision and minimum technical requirements, and a process is in place to review and evaluate these standards, with the intention that the ITU–R adopt the global IMT-2020 standard in 2020.

WRC — a key foundation for 5G delivery

A major component of 5G success is the identification of suitable frequencies for 5G and Study Group 5, through its Task Group 5/1, which has been responding to Resolution 238 (WRC-15) on mmWave spectrum bands (between 24.25–86 GHz) for IMT-2020 in preparation for decisions at WRC-19 under Agenda item 1.13. A successful outcome at the WRC will be a key foundation to the successful delivery of 5G services going forward.

RLAN technology — important for Internet access

Radio local area network (RLAN) technology (such as Wi-Fi) has developed into one of the most important means of Internet access, and Wi-Fi chipsets are imbedded into almost every mobile phone, tablet and laptop on the planet. Ensuring applications such as Wi-Fi have the spectrum needed to cater for the ever-increasing demand for data traffic is of vital importance.

To this end, the Study Group, through its Working Party 5A (WP 5A), has been looking at measures to enhance spectrum utility in the 5 GHz band in response to Resolution 239 (WRC-15) under WRC-19 Agenda item 1.16. Other important areas of work for WP 5A have been on intelligent transport systems (ITS) and on railway applications under WRC-19 Agenda items 1.11 and 1.12.


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Supporting global trade, leisure and tourism

The maritime and aeronautical sectors are hugely important, for instance for global trade and for the leisure and tourism industries. The Study Group, though its Working Party 5B (WP 5B), supports these sectors, contributing to their safe operation and navigation and to the distress and safety systems they rely on. For example, WP 5B has carried out studies to support the modernization of the Global Maritime Distress and Safety System (GMDSS) in response to Resolution 359 (WRC-15) under WRC-19 Agenda item 1.8, and other spectrum regulatory issue relevant to GMDSS responding to Resolutions 362 (WRC-15) and 360 (WRC-15) under WRC-19 Agenda items 1.9.1 and 1.9.2. WP 5B has also carried out studies on facilitating the development the Global Aeronautical Distress and Safety System (GADSS) responding to Resolution 426 (WRC-15) under WRC-19 Agenda item 1.10.

Connecting remote areas

Providing Internet connectivity to remote/sparsely populated areas, where provision through more traditional fixed and mobile networks is challenging and potentially uneconomic, is an important objective that the ITU Radiocommunication Sector is looking to facilitate.

Enhancing support for high-altitude platforms

One of the innovative ways being considered is through the use of high-altitude platforms (HAPS) and the Study Group, through its Working Party 5C, has been looking at enhanced support for HAPS in existing fixed service bands in response to Resolution 160 (WRC-15), under WRC-19 Agenda item 1.14.

The ITU Radiocommunication Sector (ITU–R) Study Groups

World experts in radiocommunications, dedicated to studies in:

The efficient management and use of the spectrum/orbit resource by space and terrestrial services

Characteristics and performance of radio systems

Operation of radio stations

Radiocommunication aspects of distress and safety matters

plus:

Preparatory studies for world and regional radiocommunication conferences

Developing global standards (Recommendations)

Publishing best practices, including reports and handbooks

More than 5000 specialists worldwide participate in the work of ITU–R Study Groups

1 Spectrum management

Spectrum management is the combination of administrative and technical procedures necessary to ensure the efficient utilization of the radio-frequency spectrum by all radiocommunication services defined in the ITU Radio Regulations and the operation of radio systems, without causing harmful interference.

3 Radiowave propagation

Propagation of radio waves in ionized and non-ionized media and the characteristics of radio noise, for the purpose of improving radiocommunication systems.

4 Satellite services

Systems and networks for the fixed-satellite service, mobile-satellite service, broadcastingsatellite service and radiodetermination-satellite service.

5 Terrestrial services

Systems and networks for fixed, mobile, radiodetermination, amateur and amateur-satellite services.

6 Broadcasting service

Radiocommunication broadcasting, including vision, sound, multimedia and data services principally intended for delivery to the general public.

7 Science services

"Science services" refer to the standard frequency and time signal, space research (SRS),space operation, Earth exploration-satellite (EESS), meteorological-satellite (MetSat), meteorological aids (MetAids) and radio astronomy (RAS) services.

ITU–R Study Group 5 (SG 5) Terrestrial services

Systems and networks for fixed service

Land mobile service and IMT

Maritime and aeronautical mobile service

Radiodetermination service

Amateur and amateur-satellite services

Four working parties (WPs) carry out the studies on Questions assigned to Study Group 5 (SG 5) and one task group (TG) which conducted studies on WRC-19 Agenda item 1.13

WP 5A

Land mobile service excluding IMT; amateur and amateur-satellite service

Read more

WP 5B

Maritime mobile service including the Global Maritime Distress and Safety System (GMDSS); the aeronautical mobile service and the radiodetermination service

Read more

WP 5C

Fixed wireless systems; HF systems in the fixed and land mobile services

Read more

WP 5D

International mobile telecommunication (IMT) systems

Read more

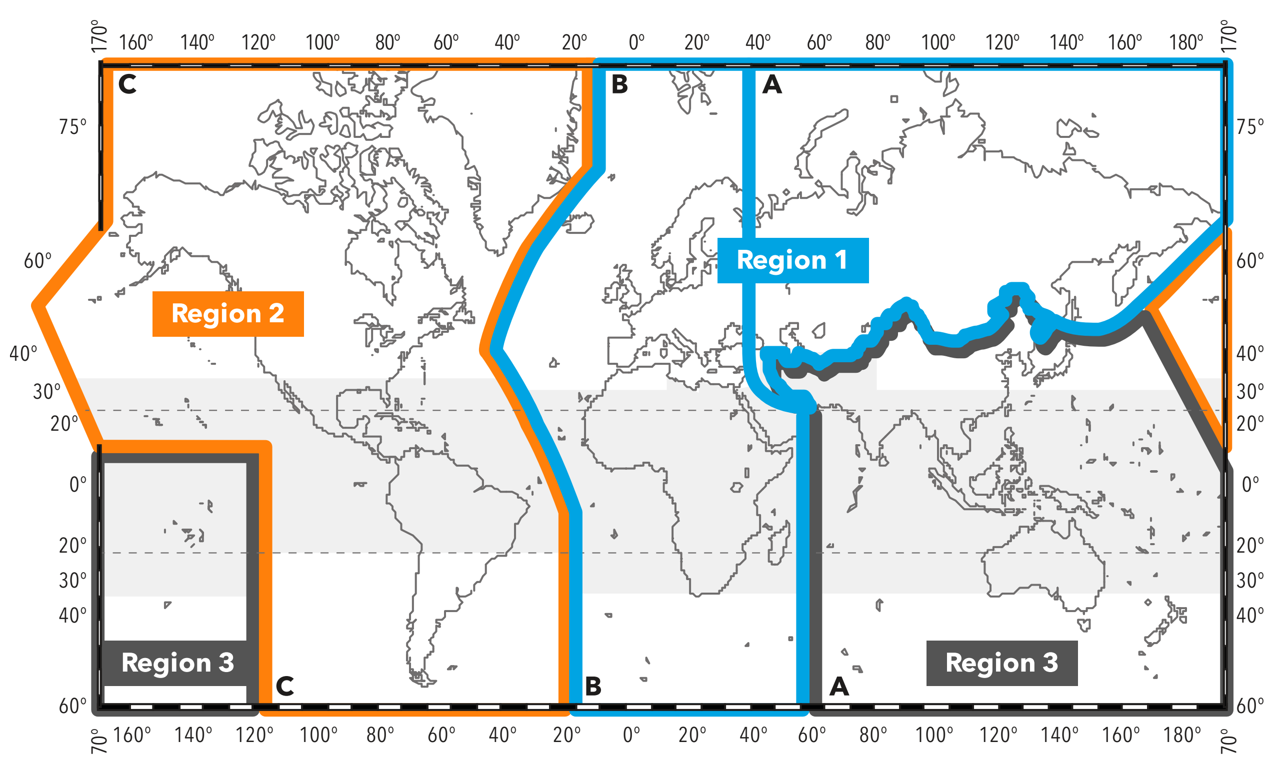
TG 5/1

WRC-19 Agenda item 1.13

Read more

For the allocation of radio spectrum frequencies the world is divided into three regions

Region 1	Region 2	Region 3
Arab States	Americas	Asia-Pacific
Africa		
Europe		
Commonwealth of Independent States		



5G is already upon us – we must act now to secure its future

Brett Tarnutzer

Head of Spectrum, GSMA

Mobile is one of the most far reaching technologies in history and the evolution to 5G is the next essential step to no one being left behind in the digital revolution. 5G is here and we are starting to see how subscribers react to ultra-fast mobile broadband, and critically, how much data they use. But, this is just the beginning, and the full picture of mind-blowing applications and speeds will only be possible when the right allocation of spectrum is made available. How this plays out will have enormous consequences for society, and if ignored, securing a better, 5G-enabled future for all, could risk being set back by a decade of progress.

In South Korea, according to SK Telecom, 5G data usage has already tripled in comparison with 4G. LG Uplus is seeing 1.3 gigabytes of data used per day per subscriber. This real-life view of how people are using 5G provides stunning evidence for the need to address spectrum planning now, to ensure that this progress is not choked off. The ITU's role is fundamental, access for everyone to the right spectrum will ultimately define the success of 5G.

“5G is not just about more speed or downloading more video — it promises to accelerate the digital transformation of all industries and sectors, and to unleash new waves of innovation that will benefit billions of people.”

Brett Tarnutzer


GSMA

5G mobile will drive the digital society

As we all know, 5G is not just about more speed or downloading more video – it promises to accelerate the digital transformation of all industries and sectors, and to unleash new waves of innovation that will benefit billions of people. The mobile industry knows how to make spectrum work for a better future. It has an outstanding record in working with governments and supranational organizations such as ITU, to effectively deploy spectrum to change lives.

But spectrum is finite, and governments need to be sure that this precious resource is maximized, not just financially, but in ways that deliver the greatest benefit to the largest number of citizens.

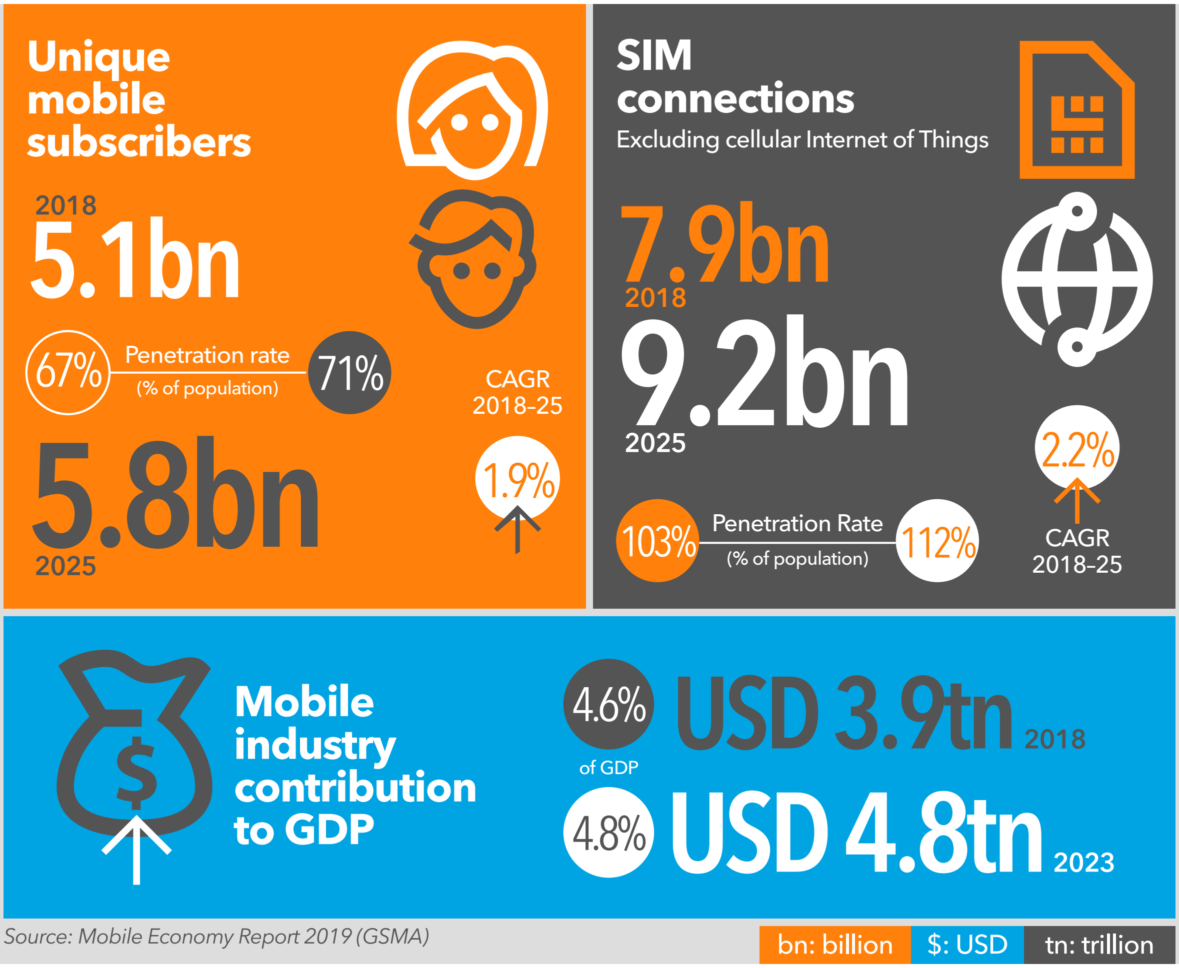
Over the past 30 years the mobile industry has made good use of its spectrum to make significant contributions to the world.

It has connected over 5.1 billion unique mobile subscribers and almost 9 billion connections, changing the way we communicate, work, manage our health, homes, and entertain ourselves.

In 2018 alone, the mobile industry contributed USD 3.9 trillion to global GDP and added USD 510 billion to public finances. But the advantages brought by the terrestrial mobile industry go far beyond commercial or even contributions to the public purse.

Mobile industry delivers with its spectrum

No-one has done more with available spectrum, nor collaborated more effectively to deliver a better future for everyone. More than two-thirds of the people on the planet are now connected to a mobile network and, for many, mobile is the primary – sometimes only – channel for accessing the Internet and life-enhancing services. Mobile is opening doors to opportunities unimaginable only a few decades ago.



Source: Mobile Economy Report 2019 (GSMA)

Our industry was the first to commit to the United Nations Sustainable Development Goals in 2016, and continues to lead by connecting less favoured communities, reducing poverty, improving access to health care and education and driving sustainable economic growth. Recently, the GSMA was proud to be awarded the Red Cross Gold medal for our efforts and commitment to humanity.

But we are fundamentally a future-focused industry. Our mission is to enable our customers to do tomorrow what they can't do today. This means providing 5G networks capable of supporting innovations such as:

- Immersive augmented reality (AR) and virtual reality (VR) educational content that can bring the world's greatest museums, sites and cultural events to potentially billions of children and adults otherwise excluded from these valuable experiences.
- Radical improvements in health care and the wellness of populations with widespread use of ultra-light, low-power wearables measuring biometrics and providing health advice in real-time.
- Creating smarter, cleaner, safer factories by connecting machinery and robots with mmWave wireless for zero-latency precision control and coordination to increase efficiency and reduce waste.

- Connecting smart cities to manage traffic, resources, power and environment in real-time at massive scale.

5G spectrum can coexist and drive new innovation

Effective allocation of spectrum, especially in the mmWave bands, is critical for these high-speed, high-throughput and low-latency scenarios.

Studies show that 5G will not only coexist alongside other uses but will accelerate the digital transformation of existing industries, and unleash a new wave of innovative solutions to our most pressing global issues.

The mobile industry is a highly-effective ecosystem, 14 million people are directly employed in the industry and 17 million people employed indirectly.

Just as 3G and then 4G networks created new disruptive businesses, from the sharing economy to wearable technology, so 5G will provide the environment for innovations in sustainability, caring for an aging population and ensuring wider and fairer access to opportunity. Allocating sufficient spectrum to international mobile telecommunications (IMT) for 5G stimulates the whole ecosystem, underpins ongoing development of existing networks, and makes sure no-one is left behind in the emerging digital society.

mmWave use cases

Large-scale industrial automation relies on mmWaves: next-generation manufacturing will produce large amounts of data, and low-latency communication is crucial.

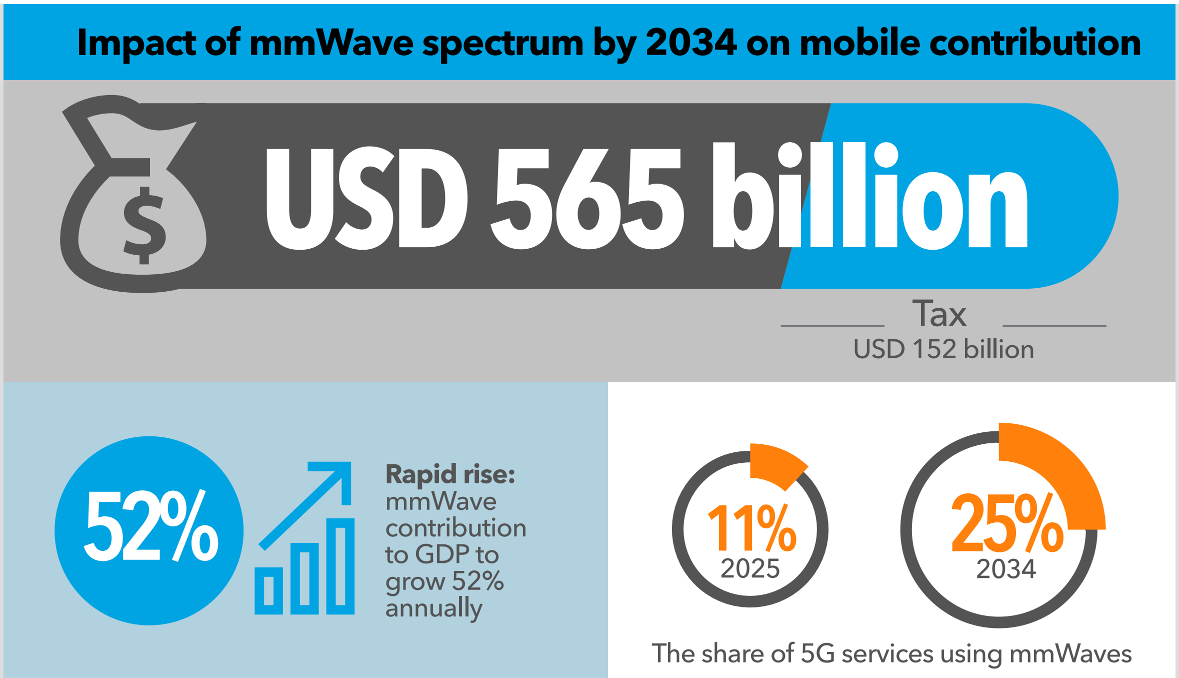
"Wireless fibre" services will be a cornerstone of early 5G; capacity will be met through mmWave along with mid-band spectrum such as the 3 GHz range.

High data volumes and high-density real-time communications must be addressed by a combination of mmWave and lower bands.

With their latency and peak data-rate requirements, mmWaves will benefit virtual and augmented reality. For example, educational applications are likely to produce high volumes of data that will rely on mmWave 5G.

Don't leave it to chance

This cannot be left to chance, and it cannot be put off. To bring the benefits of mobile services to industry and consumers, operators require timely access to the right amount and type of spectrum, and under the right conditions. In a World Radiocommunication Conference (WRC) year, these decisions need to be made, or we risk a 5–10 year "pause" on progress.



Source: GSMA

> *"In a WRC year, these decisions need to be made, or we risk a 5–10 year 'pause' on progress."*
>
> Brett Tarnutzer

To allow for 5G's full potential, specifications call for 80–100 MHz of contiguous spectrum per operator in the 5G mid-bands and around 1 GHz per operator in the mmWave bands.

The socio-economic case for allocating these bands is strong. Over a 15-year period, from 2020 to 2034, 5G services that rely on mmWaves will contribute an additional USD 565 billion in global GDP and the USD overall value created by 5G will come from mmWaves.

The ITU has played an instrumental role in enabling the creation of a better world for billions of people through its support of mobile. We all need to build on this success. Mobile operators, governments, other industries and the entire ITU membership need to work hand-in-hand to connect everyone and everything to a better future.

Global opportunities for 5G terrestrial communications

Joe Barrett

President, Global mobile Suppliers Association (GSA)

Over the past thirty+ years the mobile community has built a phenomenal global social and economic success story. The commercial drive of the mobile ecosystem and the global IMT-2020 vision means information and communications technology (ICT) connectivity can now be considered a vital utility service.

The deployment of 5G mobile technology will further extend this utility as Internet protocol-based mobile communications become the bedrock of mobile standards; and the release of new spectrum satisfies the growing service demands of both business and consumers.

ITU has played a leading role in the global success of enabling 5.7 billion users to be connected via a mobile IMT phone. The mobile industry is determined to enable the remaining 3 billion people of the world's population to also be connected by 2030 as well as 100 billion Internet of Things (IoT).

> *"Spectrum must be utilized in the most efficient and cost-effective way, and spectrum availability must not impact the commercial requirements of the broader mobile ecosystem."*
>
> Joe Barrett

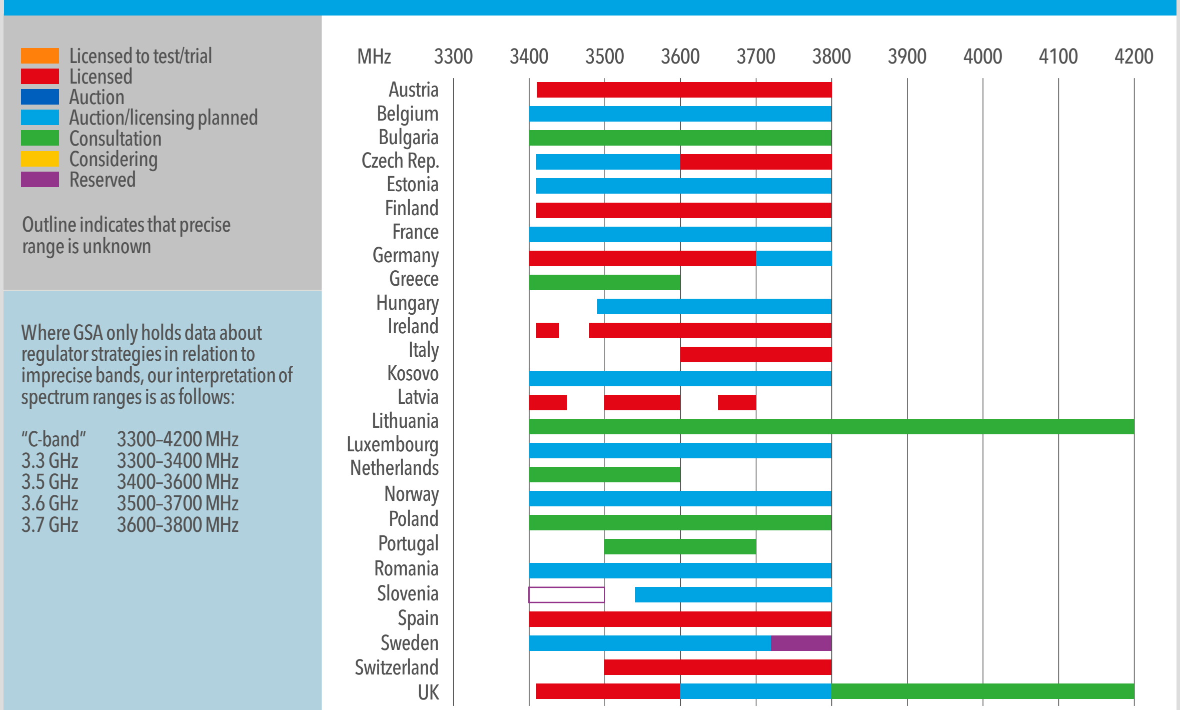
Global mobile Suppliers Association (GSA) fully expects that, with the right industry focus, 5G technology will be deployed faster than previous technology generations. According to Ovum data, 3G took 10 years to reach 1 billion subscriptions; by comparison 4G took less than six years. GSA expects 5G to take less than five years to reach 1 billion subscriptions.

The following charts show GSA's current understanding of the state of 5G and 5G-relevant (i.e. technology neutral) licensing around the world in the C-Band, 26 GHz and 28 GHz bands. The charts do not provide data about other allocations of the spectrum in these ranges – e.g. for fixed wireless access services based on LTE or WiMAX or for satellite or governmental use. The following definitions apply to the chart legends:

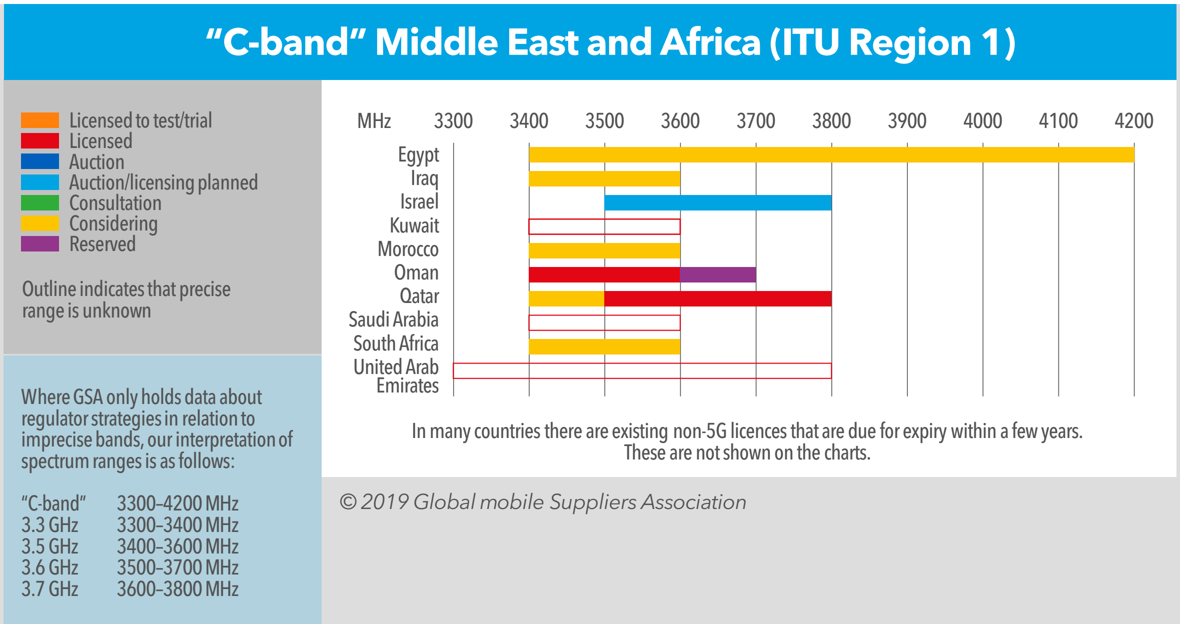
- Licensed to test/trial – temporarily licensed to run public trials using the spectrum band concerned.
- Licensed – licensed or allocated.
- Auction – auction, tender, or allocation in progress.
- Auction/licensing planned – auction, tender or allocation planned.
- Consultation – consultation ongoing.
- Considering – considering the band strategy with regard to 5G.
- Reserved – Spectrum set aside for a new entrant, or for local or private 5G networks, or for spectrum sharing, or designated for 5G but not yet allocated to a specific operator.

Outline indicates that precise range is unknown – GSA does not currently hold the data about the specific spectrum range; the activity is pictorially represented to cover the entire band.

"C-band" CEPT (ITU Region 1)



In many countries there are existing non-5G licences that are due for expiry within a few years. These are not shown on the charts.



© 2019 Global mobile Suppliers Association

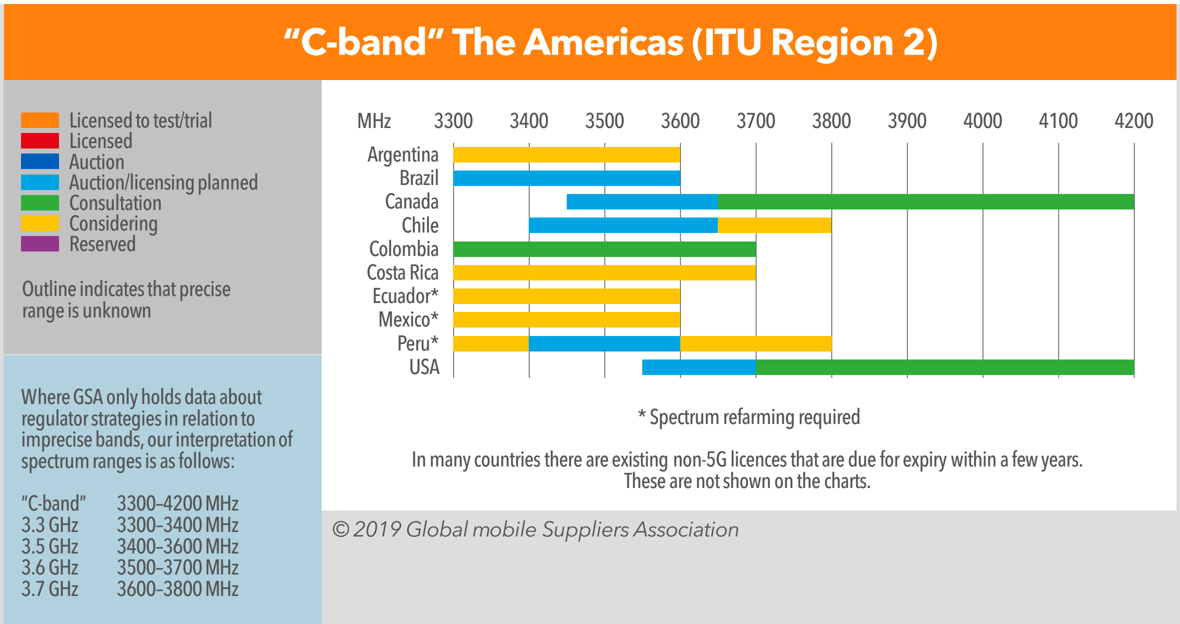
For this growth and adoption of 5G to happen three initiatives need to align:

The mobile ecosystem of global suppliers has to forward invest in 5G networks.
This is already happening with infrastructure, chip and device manufacturers accelerating the availability of 5G software and hardware, while also making economic strides in reducing the costs of deployment and management of 5G technology. Government support for 5G trials and early deployments in both developed and developing countries is also essential. According to GSA data, as of end June 2019, there were 90 announced 5G devices, twenty-five of which were phones/smartphones, based on chipsets from four silicon vendors.

GSA has also reported that infrastructure suppliers are supporting 280 Mobile Network Operators (MNOs) in 94 countries where 5G networks have either been or are being deployed, trialed, tested or where operators have been licensed to deploy mobile 5G or home broadband 5G.

The availability of 5G spectrum needs to be accelerated.
5G will require spectrum in the low bands (below 2 GHz), mid bands (2 GHz to around 6 GHz) and high bands (above 6 GHz) to achieve the full IMT-2020 vision of mobile broadband for the mass-market, including serving rural areas that have not always benefited from mobile communications. New spectrum in the high bands such as 26 GHz, 28 GHz and 40 GHz are being made available, depending on regional availability, and harmonization of these bands will facilitate the rapid deployment of the ecosystem and 5G networks. Those high bands will be important in delivering high capacity in urban hot-spots, narrow city "canyons" and in-building.

5G is also highly relevant in the low frequency bands such as 600 MHz, 700 MHz and 800 MHz, and will enable the mobile industry to deliver rural mass market home broadband along with the mid and high bands.



Mid bands offer a good balance between coverage and capacity for 5G optimal deployment in suburban areas. The mid band will be the spectrum bridge between wide coverage and high capacity services.

The high bands will help deliver the Gbps throughput required by high-quality gaming, virtual/augmented reality, video and enterprise applications due to the wider spectrum bands.

Therefore, spectrum within all three bands, low, mid and high, will be required by 5G to deliver an economically viable service if ITU is to realize its Strategic plan for the Union for 2020–2023.

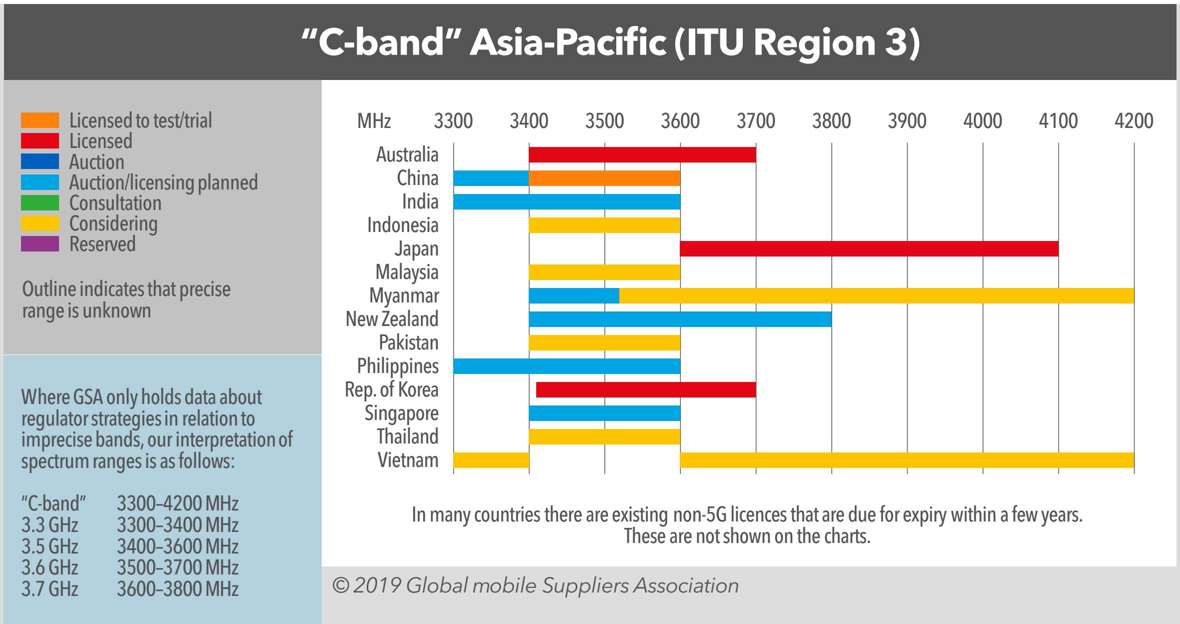
5G must reach in-building.

The quality of 3G or 4G coverage in buildings needs to improve, and is a major headache for enterprises, which will only increase in severity, since modern buildings are built to reflect radio waves. This restriction can be turned into an advantage by using the high bands in-building in addition to outdoor.

To achieve ubiquitous 5G in-building mobile broadband coverage, spectrum should be made available in the most harmonious and efficient way; either with MNOs building out dedicated in-building networks with their own licensed spectrum, or leasing or sharing licensed spectrum to enterprises, or to 3rd party in-building operators.

In addition, some regulators are considering, making part of the spectrum available to enterprises or agencies on a localized basis.

Enterprise demand for 5G is being demonstrated, and innovative applications that will utilize 5G advantages including ultra-low latency with autonomous cars, factory automation and robotics and mobile video conferencing will also require massive broadband. Spectrum must be utilized in the most efficient and cost-effective way, and spectrum availability must not impact the commercial requirements of the broader mobile ecosystem.



Expansion of the mobile ecosystem

The mobile ecosystem is expanding out of the traditional mobile supplier base to additionally include system integrators, automotive and aerospace companies, factory automation suppliers, utilities, robotic innovators, and many more.

As an industry we have a responsibility to meet the expectations of our customers and the Sustainable Development Goals. IMT-2020/5G will provide a ubiquitous, high speed and high quality, intelligent broadband connectivity experience, at home, in the office, on all forms of transport, when travelling at high speed, when in basement offices or on the top floor of a city skyrise complex, or in a rural location.

Spectrum, and the harmonization of a broad range of spectrum bands from low to mid and high, will meet and ideally exceed the expectation of all users in developed and developing countries. The industry has come a phenomenal way in a relatively short period of time.

The next challenge is to make intelligent connectivity (powered by 5G, AI and IoT) available in each corner of our world – for the global economy, and social benefits – and IMT-2020/5G mobile technology and ITU has a key role to play in making that vision a reality.

Evolving and modernizing PPDR radiocommunications

Bharat Bhatia

President, ITU-APT foundation of India

Chair, ITU–R WP5D, SWG on PPDR, Chair, APT-AWG Task Group on PPDR and Head of International Spectrum, Motorola Solutions Inc.

Radiocommunications are critical for saving lives and protecting property during emergencies, major events and disasters. Public safety agencies that respond to such emergencies cannot function without the support of robust and secure wireless communications.

“Radiocommunications are critical for saving lives and protecting property during emergencies, major events and disasters.”

Bharat Bhatia

The International Telecommunication Union (ITU), and its members realized the importance of harmonized spectrum and standard-based technologies to meet the radiocommunication needs of public safety agencies, hence the term public protection and disaster relief (PPDR – see definition at the end of article) radiocommunications was coined during the ITU World Radio Communications Conference 2000 (WRC-2000), in Istanbul, Turkey.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The critical importance of PPDR communications

PPDR communications are generally used by first responders such as the police, fire and ambulance services, civil defence forces, border guards, armed forces, search and rescue missions, etc.

PPDR communications are critical during events that threaten public safety, including threats to life, property and the environment. Such events cause havoc to the public and the local economy, including loss of lives and injuries, material losses such as destruction of property and infrastructure, as well as economic and social losses. Investments may have to be postponed, diverted to other locations, or cancelled altogether.

PPDR radiocommunications are also an important tool used on an ongoing basis by first responders in their everyday work to assist people, coordinate tasks, and dispatch resources.

The need for robust, reliable and instantaneous communications

Whether used in responding to a simple traffic accident, or a petrochemical refinery fire, the communications systems need to be robust, reliable and instantaneous. At present, most of the PPDR radiocommunication networks are based on narrowband land mobile wireless technologies such as APCO-P25 (see definition in Report ITU–R M.2377) or Terrestrial Trunked Radio (TETRA). These narrowband networks are built for mission critical voice communication, support instantaneous push-to-talk group and device to device communications but have limited data capabilities. WRC-2003 adopted Resolution 646 (last revised at WRC-15 (see the Resolution below)) to harmonize the spectrum needed for such systems on a regional basis.

Real time — an urgent requirement

With the explosive growth and proliferation of smart mobile phones supported by broadband with high speed internet access, video and real time social media in the hands of general public (and criminals), PPDR agencies have realized an urgent need to access broadband data, social media and mobile videos in real time. In particular, high-resolution videos from the scenes of disasters or other major events are becoming increasingly critical for real-time situational awareness and intelligence-driven decisions.

New PPDR applications using real-time mobile video are helping detect and prevent criminal and other unlawful activities as well as supporting effective response to disaster events. The fusion of artificial intelligence, mobile videos and big data technologies is enabling video content analytics that support detection, tracking, extracting and identifying people, objects and their attributes.

Such advanced PPDR applications are already supporting crime prediction and crime prevention. Mission critical integrated voice and video conversations integrated with information on the location of emergency responders, real-time updates on public transport movements and even social media activities are helping PPDR agencies in responding to major events.

Mobile broadband PPDR networks could also enable fingerprint sensors to identify criminals or victims at the scene of an incident, saving valuable time and gathering vital intelligence in the moments that matter.

These networks can also enable live feeds from traffic cameras or drones, or the use of number-plate recognition in real time to track and intercept suspects before members of the public are put at risk.

Harmonizing spectrum for broadband PPDR

Timely availability of harmonized radio frequency spectrum is important for realizing dedicated broadband PPDR networks. The ITU World Radiocommunication Conference 2015 (WRC-15) revised and updated Resolution 646 (Resolution 646 (Rev. WRC-15). to harmonize spectrum needed for broadband PPDR on a global as well as regional basis. The frequency range 694–894 MHz was adopted by WRC-15 as the globally harmonized frequency range for broadband PPDR. This frequency range includes the most commonly used PPDR bands in 700 MHz (3GPP bands 14, 28 and 68) and 800 MHz (3GPP bands 5, 20 and 26).

In order to develop the new features and applications required by PPDR users such as Mission-Critical Push To Talk (MCPTT), Mission-Critical Data (MC Data), Mission-Critical Video (MC-Video) and Device-to-Device (D-to-D) communications, the Third Generation Partnership Project (3GPP) has created a working group (System Architecture SA6). The applications are progressively being built into IMT (see Report ITU–R M.2291) technology, starting with long-term evolution (LTE) release 13 and continue to evolve and mature in specifications of Releases 14, 15 and 16, and going into IMT-2020.

The challenge of how to establish broadband PPDR

As broadband data rapidly becomes a necessity for PPDR users, many governments around the world are faced with the challenge of how to establish broadband PPDR communications. Building new PPDR infrastructure for the coming decades requires radio spectrum resources, financial resources, infrastructure sharing of towers and sites, right of way rules and decisions on a governance model to be followed, as PPDR users historically belong to multiple agencies and operate under different jurisdictions. Broadband PPDR networks must meet the operational and functional requirements of PPDR agencies and be robust, secure and have the geographical coverage and capacity to provide mission-critical broadband services, such as real-time video communications and real-time data.

A number of countries have already implemented dedicated broadband PPDR networks. Others have dedicated harmonized spectrum for PPDR and a contracted service provider to build and operate the networks for them. Few have opted for commercial carriers to provide them infrastructure as a service (IaaS) against long-term contracts and operational requirements with specific quality of service norms.

Radiocommunication objectives and requirements for Public Protection and Disaster Relief

Public Protection and Disaster Relief (PPDR) radiocommunication systems are vital to the achievement of the maintenance of law and order, response to emergency situations, protection of life and property and response to disaster relief events.

The ITU Radiocommunication Sector (ITU–R) Report M. 2377 discusses the broad objectives and requirements of PPDR applications, including the increasing use of broadband technologies to meet those objectives and requirements. The expanding scope of PPDR capabilities, ranging from narrowband through wideband and broadband, offers greater utility for emergency response operations around the world, including in developing countries.

The advances in broadband technologies offer the potential of enhanced capability and capacity to facilitate the achievements of both public protection operations and responding to major emergencies and catastrophic disasters. Whilst noting that narrowband and wideband technologies for PPDR services and applications are still widely used in all three ITU Regions.

Lean more in Report ITU–R M.2377.

Public safety and the 700 MHz band

The First Responder Network Authority (FirstNet) nationwide public safety LTE (PS-LTE) network in the United States, in the 700 MHz band, is the first example of a large broadband PPDR data network to supplement the country's statewide P25 narrowband mission-critical voice network that equips first responders to save lives and protect communities. A nationwide LTE network in the 700 MHz band is also being implemented in South Korea to supplement its existing TETRA mission critical voice network. Similar networks are under implementation in many countries around the world including the Emergency Services Network (ESN) in the United Kingdom, and similar networks in the Middle East and some Asian countries.

Radio interface standards for use by public protection and disaster relief operations in accordance with Resolution 646 (Rev. WRC-15)

The ITU Radiocommunication Sector's Recommendation M.2009-2 identifies radio interface standards applicable for public protection and disaster relief (PPDR) operations in accordance with Resolution 646 (Rev. WRC-15). The broadband standards included in the Recommendation are capable of supporting users at broadband data rates, taking into account the ITU–R definitions of "wireless access" and "broadband wireless access" found in Recommendation ITU–R F.1399.

The Recommendation addresses the standards themselves and does not deal with the frequency arrangements for PPDR systems, for which a separate Recommendation exists: Recommendation ITU–R M.2015.

The Recommendation ITU–R M.2009-2 also addresses radio interface standards for use for public protection and disaster relief operations. These standards are based on common specifications developed by standards development organizations (SDOs). Using this Recommendation, regulators, manufacturers and PPDR operators should be able to determine the most suitable standards for their needs.

To learn more about the recommendation, and for details of various PPDR technologies, see Recommendation ITU–R M.2009-2.

Modernizing and transforming PPDR operations to respond to evolving challenges requires substantial investments in infrastructure, work-flow, systems and applications. Regardless of the approach chosen, the availability of funds to deploy, maintain and secure a PPDR capable infrastructure requires government planning for funding and securing and policy decisions in a stable regulatory environment. Mission critical intelligence and real-time data analytics and multimedia dispatch capabilities are becoming just as important as push-to-talk voice in responding to PPDR agencies communication needs.

In the coming years, LTE-advanced and 5G networks will enable enhanced mission critical applications requiring ultra reliable low latency and high mobility designed to meet the high demands of mission critical video and data by the PPDR agencies.

The ITU Radiocommunication Sector (ITU–R) is also working towards defining the future role of IMT-2020 to support PPDR applications.

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Intelligent transport systems towards automated vehicles

Satoshi Oyama

Senior Researcher, Association of Radio Industries and Businesses (ARIB), Japan

There are about 1.4 billion cars in the world, with an average annual increase of 4% per year. Meanwhile, according to the World Health Organization, traffic fatalities in the world amount to 1.35 million individuals per year.

Intelligent transport systems (ITS) represent the integration of information and communication technologies (ICTs) and applications that can achieve a reduction in traffic and pedestrian fatalities, and enhance transport infrastructure systems, through the realization of future automated driving.

Connected and automated vehicle technologies can gradually eliminate the need for drivers; reduce transportation costs, traffic accidents, fatalities, injuries, and CO_2 emissions; improve traffic flow and reduce travel time; and provide transportation accessibilities. Ultimately, self-driving cars are projected to reduce traffic fatalities by 90%.

In the ITU Radiocommunication Sector (ITU-R), various studies, Recommendations and Reports are addressing the transition from ITS to automated vehicles.

"The ITU World Radiocommunication Conference 2015 (WRC-15) initiated Agenda item 1.12 to seek globally or regionally harmonized spectrum for ITS applications."

Satoshi Oyama

Three generations of intelligent transport system deployment

As the "first generation" of ITS deployment, electronic toll collection (ETC) systems and vehicle information and communication systems (VICS) have been widely deployed in the world.

The "second generation" witnessed the emergence of dedicated short-range communication (DSRC) systems and collision avoidance radar, as well as the integration of radiocommunication and radiolocation technologies for vehicular applications.

The "third generation" revolves around the research and development to enable connected cars and fully automated driving systems. ITU–R has been, and is, central to this evolution, as the identification and harmonization of frequencies, especially radiocommunication spectrum in the mobile service depending on the application, are the necessary foundation for any deployment.

ITU Working parties 5A and 5B for ITS

Specifically, radiocommunication technologies and technical/operational characteristics for ETC, VICS and DSRC were developed and standardized in ITU–R, in Working Party 5A in particular.

Mobile wireless communications, such as cellular, radio local area network (RLAN), etc. are now also being considered for ITS applications, such as traffic information systems and info-communication systems.

As a radiolocation sensor, standards for 79 GHz short-range vehicular radar were developed and completed in ITU–R Working Parties 5A and 5B – the responsible groups for such studies. This millimeter wave radar is expected to integrate with radiocommunication systems to enable automated driving vehicles.

Towards automated driving — V2X deployment in Japan

In 2015, ITS Connect was introduced in Japan to use vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) radiocommunications, collectively known as "V2X", using 760 MHz DSRC to provide drivers much needed safety information that cannot be picked up by onboard sensors. This includes traffic signal information and information about the presence of vehicles and pedestrians in blind spots. V2X is expected to reduce the number of accidents in Japan by roughly 40%.

V2I communications, for example, provide right-turn collision caution. While waiting for a right turn at an intersection, drivers are warned by audio and visual alert on the monitor regarding cross traffic such as pedestrians. This is also a critical technology for pedestrians with hearing disabilities or visual impairment.

V2I communications also provide approaching red light caution. When approaching an intersection with a red traffic signal, the system will warn the driver with audio and visual alerts on the monitor, and may overtake the driver controls by stopping the vehicle.

Source: TOYOTA Motors

V2V communications provide radar-based cruise control communications with other vehicles in order to maintain safe distances and minimize speed fluctuations.

When an emergency vehicle equipped with an ITS Connect DSRC unit is approaching with its sirens, V2V communications provide drivers the approximate location and distance of the emergency vehicle, as well as the direction in which it is moving.

In Japan, ETC is now upgraded to ETC2.0. In addition to current ETC features, ETC2.0 integrates additional features to provide supporting information such as for safe driving, congestion avoidance, and emergency and disaster response conditions, while using the same 5.8 GHz DSRC spectrum.

ITS standardization activities in ITU–R

Since 1994, ITU–R Working Party 5A has been developing Recommendations and Reports for ITS based on ITU–R Question 205. A new ITU–R Question on "Connected automated vehicles (CAV)" is under consideration for adoption and approval by ITU–R Study Group 5 (in September 2019) to address the standardization requirements for automated vehicles.

In ITU–R Working Party 5A, Recommendation ITU–R M.2121: *"Harmonization of frequency bands for Intelligent Transport System in the mobile service"* describes global or regional harmonized frequencies for the 5.8/5.9 GHz bands, and the existing 760 MHz band for ITS applications.

> *"A new ITU–R Question on "Connected automated vehicles" is under consideration for adoption and approval by ITU–R Study Group 5 to address the standardization requirements for automated vehicles."*
>
> Satoshi Oyama

Report ITU–R M.2444 *"Examples of arrangements for Intelligent Transport Systems (ITS) deployments under the mobile service"* provides supplemental information for Recommendation ITU–R M.2121. While Report ITU–R M.2445 *"Intelligent Transport System (ITS) usage"* includes long-term evolution (LTE)-based V2X requirements and applications.

For automated vehicles, millimeter waves above the 60 GHz band are under study as supplemental spectrum, such as for the trucks and trailers platooning system.

WRC-19 Agenda item 1.12 – ITS applications

The ITU World Radiocommunication Conference 2015 (WRC-15) initiated Agenda item (AI) 1.12 to seek globally or regionally harmonized spectrum for ITS applications.

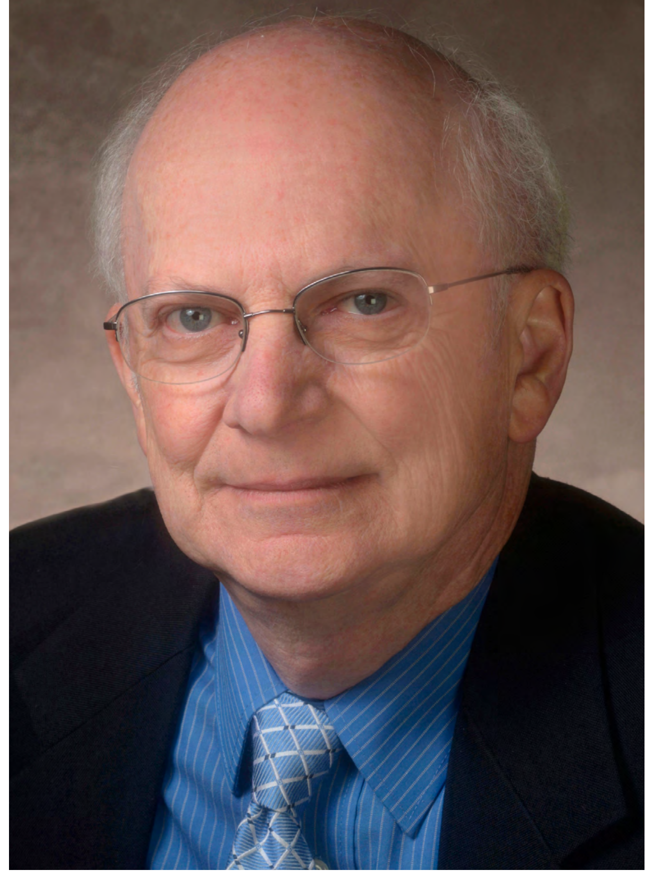
At WRC-19, the conclusion of AI 1.12 seeks to adopt a WRC Resolution which describes such spectrum in an ITU–R Recommendation (i.e. Recommendation ITU–R M.2121) to accelerate the development of ITS systems and technologies to fully realize the deployment of automated and connected vehicles.

Connected vehicles are no longer in the distant future; they are available now.

Self-training, intercommunication and technical investigations: the amateur service in the 21st Century

David Sumner

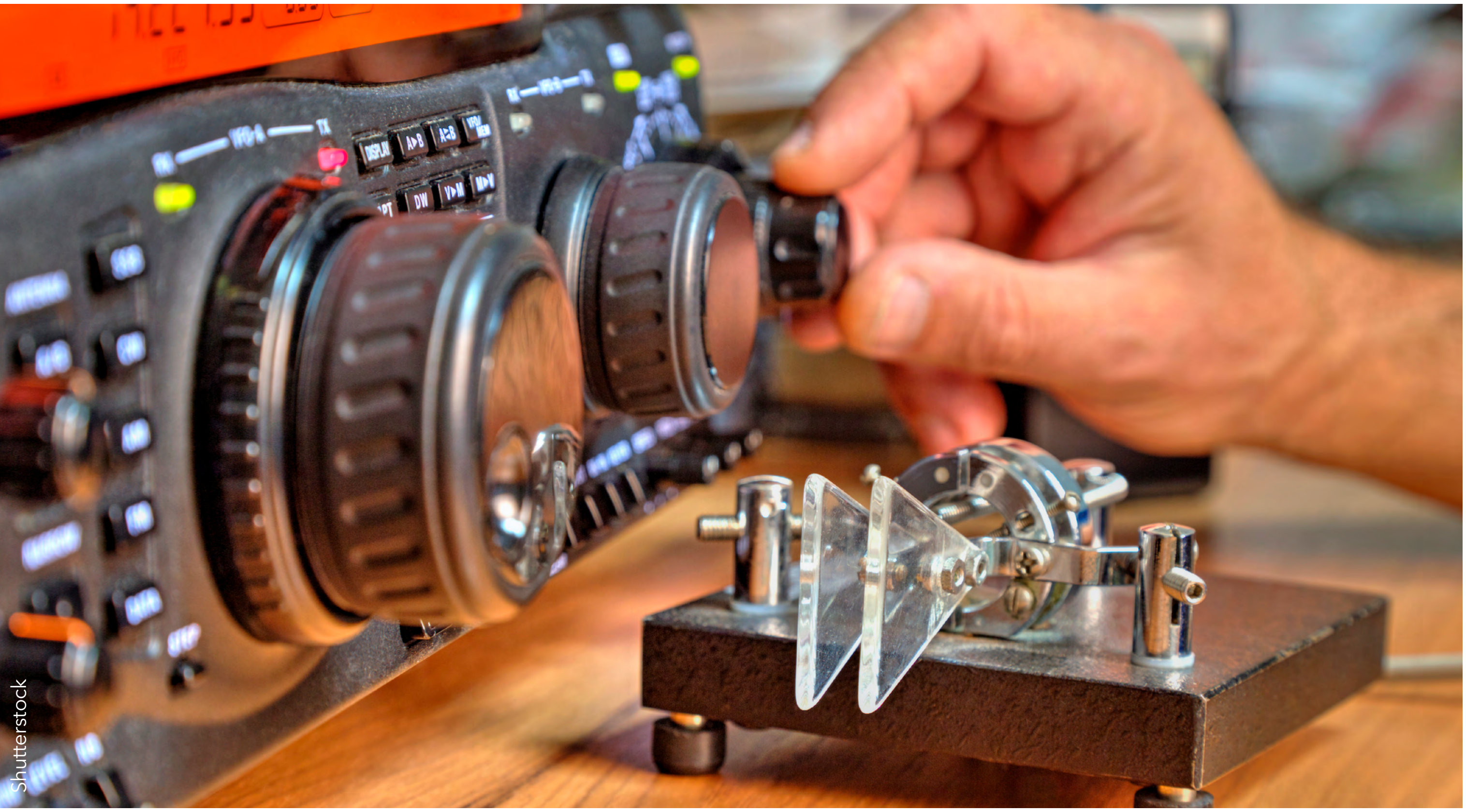
Secretary, International Amateur Radio Union (IARU)



The amateur service is one of the oldest radio services, predating regulation. Recalling his earliest experiments, Marconi proudly referred to himself as an amateur. Today more than three million radio amateurs throughout the world follow in his footsteps and those of other radio pioneers, motivated by curiosity, and the desire to understand and harness the natural phenomena that influence radiowave propagation.

In so doing, they expand the body of human knowledge and technical skills that are essential to development, and offer a resource that can literally save lives when natural disasters disrupt normal communications channels, all at very low cost.

> *"Amateur licensees are grateful that ITU Member States continue to recognize the benefits of providing direct access to the radio spectrum to qualified individuals."*
>
> David Sumner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Who are radio amateurs?

Radio amateurs come from all economic, social, cultural, and educational backgrounds. Each has earned a licence from his or her administration by demonstrating operational and technical qualifications in accordance with the ITU Radio Regulations (RR) 25.6. In return they gain the privilege of operating a station for non-commercial two-way communication and experimentation within the framework of the RR, and as authorized by their administration. Countless students have discovered their passion for electronic communication through amateur radio and have gone on to rewarding careers in technology and related fields.

What do they need from ITU?

Amateur licensees are grateful that the ITU Member States continue to recognize the benefits of providing direct access to the radio spectrum to qualified individuals. Access to frequency bands spaced throughout the radio spectrum is essential to the continued success of the amateur service. This pattern of amateur allocations was established at the International Radiotelegraph Conference (Washington, 1927) and has been extended at subsequent conferences, most recently at the World Radiocommunication Conference (WRC-15) with the addition of a narrow secondary allocation near 5.3 MHz. Today the international Table of Frequency Allocations includes amateur bands from 135.7 kHz (WRC-07) to 250 GHz.

Most amateur service allocations are on a worldwide basis, but some are limited to one or two of the three Regions (see the regional spectrum allocation map on page 13). Harmonized allocations highly facilitate intercommunication. The first item on the WRC-19 agenda is to consider the allocation of the band 50–54 MHz to the amateur service in Region 1, to align with the existing allocations in Regions 2 and 3.

> *“The first item on the WRC-19 agenda is to consider the allocation of the band 50–54 MHz to the amateur service in Region 1, to align with the existing allocations in Regions 2 and 3.”*
>
> David Sumner

At the 1979 World Administrative Radio Conference ITU Member States agreed to extend terrestrial allocations above 40 GHz for the first time. Included at appropriate intervals beginning at 47 GHz were co-primary allocations to the amateur and amateur-satellite services, along with other allocations on a secondary basis, to permit the greatest flexibility for the exploration of the propagation characteristics of millimeter wavelengths.

Amateurs have established two-way communication repeatedly over paths of more than 300 km at 47 GHz and of more than 200 km at higher frequencies. If a future World Radiocomunication Conference (WRC) extends allocations above 275 GHz, adequate provisions for amateur experimentation should be made.

Amateurs are particularly concerned about electromagnetic compatibility with devices that are likely to be near their stations, usually in their homes and vehicles.

Through its regulations and standards ITU plays an essential role in preventing radio spectrum pollution from unintentional emitters of radio frequency energy and other unwanted emissions.

While this is important for all radiocommunication services, it is especially vital to the amateur service, which uses sensitive receivers to compensate for practical and regulatory limitations on antennas and transmitter power levels.

Extending frontiers

In addition to extending the frontiers of frequency and wavelength, amateurs are refining communication protocols by optimizing coding, modulation, and digital signal processing to improve weak-signal performance. This endeavour is being conducted by an international team led by Dr Joseph H. Taylor, Jr., who earned the Nobel Prize in physics in 1993 for his groundbreaking work in radio astronomy that led to the discovery of binary pulsars and subsequent observations that confirmed the existence of gravitational radiation.

During the 2012 World Radiocommunication Conference Dr Taylor was awarded the ITU Gold Medal in recognition of his outstanding contributions to research in the field of radiocommunication research that he began as a radio amateur while still in high school.

The original social network

As the first electronic community that bridged geographic, cultural, and social barriers, amateur radio is sometimes called "the original social network." The tradition continues today. Meeting people "on the radio" with whom you share an interest is enjoyable in itself but also provides hands-on experience that develops skills and capabilities that can be invaluable in providing communication when telecommunication services are damaged or disrupted by natural disasters.

With a low-power high-frequency (HF) transceiver, a car battery, and wire for an antenna, a skilled amateur can establish communication from virtually anywhere using his or her knowledge of ionospheric propagation. Local amateur emergency networks rely heavily on the frequency band at 144 MHz, which is the only global primary allocation to the amateur service between 29.7 MHz and 24 GHz.

The IARU's contributions to the work of ITU

Representing the interests of radio amateurs is the mission of the International Amateur Radio Union (IARU), a federation of national associations in more than 140 ITU Member States. The IARU's contributions to the work of ITU began with its admission to participation in the work of the CCIR (International Radiocommunication Consultative Committee) in 1932, and continue to the present day in both the Radiocommunication and Development Sectors (ITU–R and ITU–D).

The IARU is proud to be an active member of the ITU community.

■

High Altitude Platform Stations (HAPS) – bringing connectivity to all

Michael Tseytlin
Director of Engineering, Spectrum and Standards, Facebook

Chris Weasler
Head of Global Spectrum Policy and Connectivity Crisis Response Program, Facebook

As emerging economies around the world focus on digital transformation as a path toward socio-economic empowerment, bringing connectivity to all is increasingly critical. Nearly half of the world's population is still not connected to the Internet. Among those that have connectivity, many are under-connected. Connecting these people requires not just bringing network infrastructure to more people, but establishing a regulatory environment that fosters innovation and encourages investment.

"HAPS systems have the potential to become an important tool for bringing broadband to hard-to-reach and unserved areas."

Michael Tseytlin/ Chris Weasler

To do its part, Facebook, working with a range of partners, has launched several initiatives focused on connecting unserved and underserved communities. Connecting everyone will require a mix of technological solutions. So Facebook has been investing in research and development for a range of technologies, including mobile, satellite, and aerial, like high altitude platform stations (HAPS).

HAPS are stratospheric stations, each composed of an aerial vehicle and a payload that operate at around 20 km above ground. HAPS systems have the potential to become an important tool for bringing broadband to hard-to-reach and unserved areas, supplementing existing networks to meet ever-increasing demand, and serving as "instant infrastructure" in emergency communications and disaster relief.

Why HAPS?

First, HAPS can be deployed quickly to cover wide service areas — approximately a 50 km radius — over any type of geography, including difficult terrain, because minimal ground infrastructure is required.

Second, HAPs are reliable. Advances in aeronautics, as well as battery and solar power technology, allow HAPS to operate continuously for long periods of time without many of the risks that other networks face (e.g., accidental damage, theft, conflict areas, and natural disasters).

Third, HAPS systems are broadband-capable, thanks to unprecedented advances in communication technologies.

These features make HAPS economically viable as backhaul for broadband and 5G, as part of both terrestrial and satellite networks in areas where other technologies may be hard to deploy due to difficult terrain or long distances from population centres. Additionally, HAPS can provide "instant infrastructure" to extend connectivity rapidly during natural disasters.

> *"The technological development and commercial maturity of HAPS has been fuelled by a growing industry ecosystem."*
>
> Michael Tseytlin/ Chris Weasler

HAPS development — fuelled by a growing industry ecosystem

The technological development and commercial maturity of HAPS has been fuelled by a growing industry ecosystem that includes leaders in the communications, content, and aerospace sectors. Over the last fifteen years, a significant number of global aeronautical manufacturers have invested in developing HAPS technology. And there is also commercial interest from terrestrial partners that seek to leverage HAPS's cost-effective backhaul capabilities to enable terrestrial network deployment in unserved and underserved areas. Satellite operators too have also shown an interest in incorporating HAPS into their networks to facilitate access to data-intensive applications in remote areas. For example, HAPS could be used to create a "hotspot" of concentrated capacity where needed within large satellite footprints.

More harmonized spectrum needed to fulfil the promise of HAPS

The missing enabler for the short-term commercial rollout of HAPS remains access to sufficient globally harmonized spectrum. This will drive the technology's affordability, and capability to contribute in closing the digital divide.

The spectrum needs of broadband HAPS systems cannot be fully accommodated within existing ITU identifications due to geographical restrictions or technical limitations. Therefore, at the upcoming World Radiocommunication Conference (WRC-19), ITU Member States will consider modifications to existing regulations to increase spectrum access for HAPS in millimeter wave bands under Agenda Item 1.14.

Extensive studies carried out by multiple parties at the ITU Radiocommunication Sector (ITU–R) Working Party 5C demonstrated that HAPS can be deployed in bands under consideration while protecting incumbent services. Flexible use of these bands can be enabled with properly-defined ITU–R regulatory constraints on HAPS such as PFD limits at the border and out-of-band emission limits.

Agenda Item 1.14 has garnered support from across regions, notably in Europe, Africa, as well as in the Americas. Regions with large unconnected populations (and compelling use cases for HAPS) have taken a leading role in regulatory discussions on this topic: the African Telecommunications Union (ATU) expressed its support for this initiative to improve global broadband access during its last WRC-19 preparatory meeting, and African subregions have developed proposals to identify spectrum for HAPS on a co-primary basis with other services. See the African Telecommunications Union Report of the 3rd African Preparatory Meeting for World Radiocommunication Conference 2019 (APM19-3) (Sep. 2018) at 8 (supporting the designation of certain fixed service bands for HAPS, in accordance with Resolution 160 (WRC-15)). See sidebar for more on ITU studies on HAPS.

Similar positions have been developed by the Inter-American Communications Commission (CITEL) and have reached the status of Draft Inter-American proposals and Inter-American proposals due to the support of multiple administrations across the continent.

ITU studies on HAPS

The International Telecommunication Union (ITU) is studying HAPS identifications in millimeter wave spectrum bands including the 26 GHz band.

Resolution 160 resolves that the ITU–R will study the existing HAPS identification of 27.9–28.2 GHz (paired with 31.0–31.3 GHz) as appropriate 38-39.5 GHz.

In addition, in Region 2, the ITU–R will study 21.4–22 GHz and 24.25–27.5 GHz. See id. See Resolution 160 (WRC-15).

Technological advances and the growth of a mature business ecosystem around stratospheric connectivity technologies make HAPS a viable solution to complement extend reach and applications of broadband networks.

To fulfill the promise of HAPS, ITU Member States may wish to give proper attention to Agenda item 1.14, and proposals for identification of harmonized frequency bands for HAPS at WRC-19.

Connectivity from the stratosphere

Sophie Thomas

Zephyr Programme Manager, Airbus

Zephyr has made stratospheric flight a reality

On 11 July 2018, a Zephyr S aircraft took off on its maiden flight in Arizona. It flew for 25 days, 23 hours and 57 minutes, marking the longest flight duration ever achieved without re-fuelling. The Zephyr aircraft has also flown in excess of 74 000 feet and repeatedly demonstrated an ability to remain in the stratosphere overnight. These achievements of un-interrupted and persistent flight have proven the readiness of Zephyr as a platform capable of delivering connectivity services from the stratosphere, and are the result of a 15-year journey.

"Committed to success for HAPS at the upcoming WRC-19 in November, Airbus is focused on broadening the previous HAPS allocations."

Sophie Thomas

Flying above the weather, providing persistent coverage

Zephyr is an ultra-light solar-powered high-altitude platform station (HAPS). Solar energy powers daytime flight as well as re-charging batteries for night-time operations. It has a 25 metre wingspan (one third the width of an Airbus A380) and can launch from a selection of sites strategically positioned across the globe.

Airbus Zephyr taking off on its world record flight from Arizona in 2018

Zephyr flies above the weather and regular air traffic, covering distances of over 1000 nautical miles a day — that's 1852 kilometres! Of particular interest to telecoms operators is Zephyr's ability to remain persistent over a designated location for long periods of time, delivering connectivity services across a wide area.

Optimum power to weight ratio

Zephyr weighs less than 75 kilograms, the same as two aircraft seats. It is this highly optimized aircraft mass, together with the available power of the Zephyr propulsion system and the high efficiency of the solar cell technology, which permits Zephyr to remain continuously within the stratosphere after launch, day after day, performing station keeping, mission specific manoeuvres and providing sufficient power for connectivity payloads during service delivery.

An optimized power-to-weight ratio ensures that Zephyr can remain above a minimum dawn altitude (the point at which battery capacity is typically at its lowest), which is acceptable for delivery of service.

Production is rolling

The Zephyr-S aircraft that set the endurance benchmark in Arizona was the first serial production Zephyr aircraft. In July 2018, Airbus opened a dedicated Zephyr production facility in Farnborough (United Kingdom), the world's first HAPS assembly line. In addition, Airbus has established a permanent operations and evaluation facility in Wyndham, Western Australia. The site has been operational since September 2018 and has been selected due to the largely unrestricted surrounding airspace and reliable weather conditions.

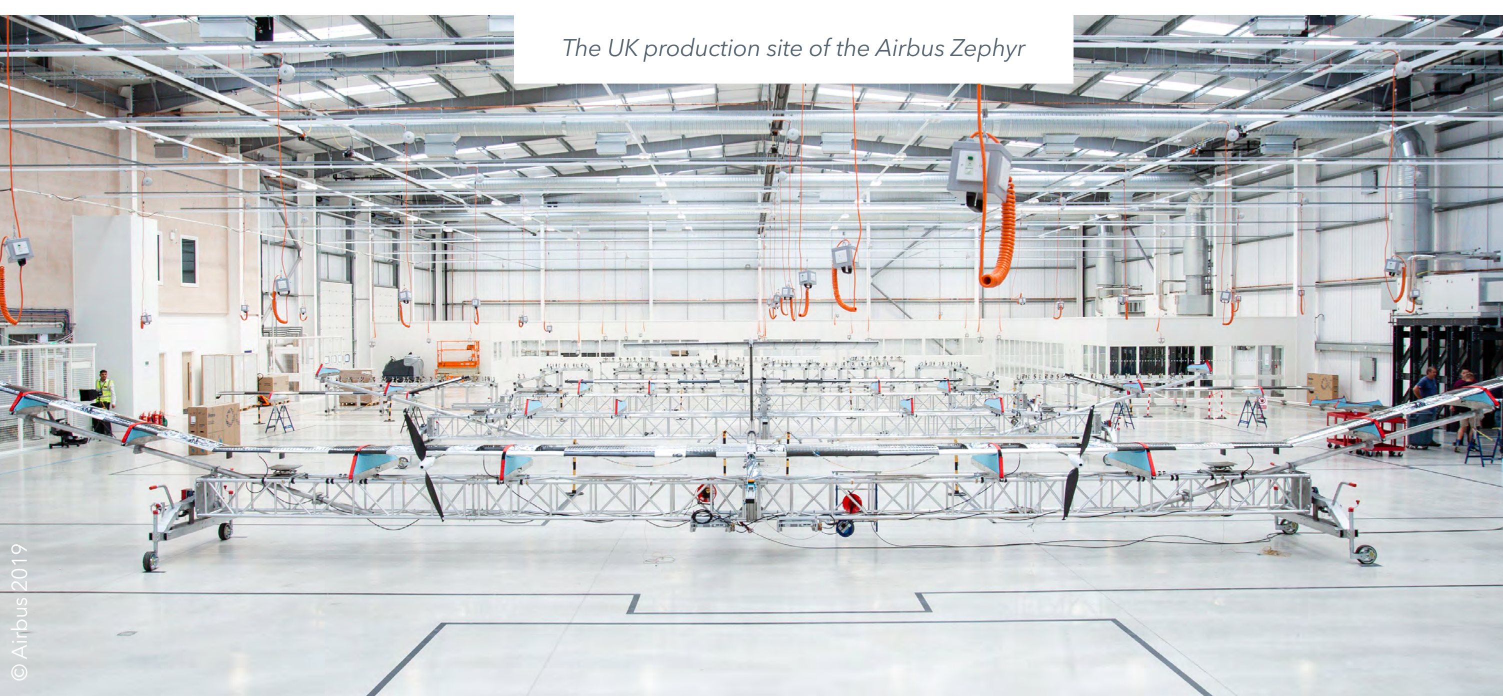
Delivering connectivity

The Zephyr platform provides a unique combination of advantages for the delivery of connectivity services:

- **Persistence:** Providing controlled coverage over a designated area. The tight station-keeping capabilities of Zephyr have been well proven in flight trials.
- **Low-latency:** Zephyr is close enough to ground stations to have little latency and offer real-time services.
- **Flexibility:** The ability to re-position/re-task the platform after launch. Providing the ability to re-deploy connectivity assets to areas where demand is peaking.
- **Scalability:** The ability to add/remove aircraft to adjust the combined footprint of a Zephyr constellation.
- **Rapid Evolution:** Aircraft can be fitted with enhanced payload capabilities and returned to service rapidly with enhanced performance/coverage capabilities as technology advancements become available. The same is true of platform technologies which can extend the life and service intervals for aircraft.

Connectivity markets

Configured with the corresponding payload Pod, the Zephyr platform is able to provide a range of connectivity applications: public protection disaster relief (PPDR), emergency communications, theatre backhauling, cellular backhauling, 5G connectivity, direct to device communication and direct to home services. In the near term, Zephyr will provide cellular backhaul services to rural and semi-urban under-served regions, and where temporary capacity is required.


The UK production site of the Airbus Zephyr

Low-latency performance and the ability to provide lower data rate services across wider areas makes Zephyr well suited to the Internet of Things (IoT)/machine-to-machine (M2M) connectivity applications. In the military and institutional markets, the high availability of service offered by Zephyr makes it ideal for resilient secure networks and radio-relay applications.

As well as supplementing existing connectivity infrastructure in highly-developed regions, Zephyr will be able to connect the unconnected, support the under-connected, and open new regions and segments. Market demand will be driven by lower capital expenditure (CAPEX) investment, short lead-times and operational flexibility, which make the decision to go with HAPS connectivity low risk.

The ability to quickly add a high throughput capability over a desired region of demand makes Zephyr an attractive proposition to telecom operators for key applications such as surge provisioning, expanding network coverage and filling connectivity black spots. As such, the ability of Zephyr to integrate with existing ground infrastructure, and be interoperable within an established eco-system of affordable terminals, will make it a good fit in these segments.

The key geographic areas that will have a high interest in HAPS connectivity are within countries with relatively high populations, high average revenue per user (ARPU), but poor terrestrial infrastructure, particularly within but not limited to equatorial regions. Zephyr is predicted to take a significant share of the HAPS market. The connectivity segment alone is estimated to require thousands of aircraft across the globe.

WRC-19

In recent years, Airbus has been at the forefront of championing spectrum allocation for HAPS. As part of its current campaign, the company has held close dialogue with relevant stakeholders, national and regional administrations, mobile and fixed-service satellite communities, and smaller but significant stakeholders such as the radio astronomy community. Committed to success for HAPS at the upcoming WRC-19 in November, Airbus is focused on broadening the previous HAPS allocations to serve the backhauling and PPDR segments.

Working with partners

Airbus is working closely with payload providers and operators to refine and demonstrate the required technologies, concept of operations and commercial business models for connectivity. Driven by the knowledge that no single connectivity platform or technology will be sufficient to meet the forecast global and regional demand for connectivity, Airbus is keen to engage with the wider HAPS community and with technology partners to create connectivity solutions which will complement current and planned terrestrial and satellite communication technologies.

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A revolution in railway communication

Dirk Schattschneider

Senior Spectrum Manager, Deutsche Bahn AG

Today's constantly increasing individual traffic and the threatening traffic collapse and climate change, are forcing more and more governments to look for alternative transport options. Shifting traffic from the road to the railways is the way out, as rail transport systems are by far the most environmentally-friendly means of transport.

"The railway sector is facing one of its biggest challenges ever — the revolution in railway communication."

Dirk Schattschneider

Four categories of railway communication applications

Since the beginning of railway operations, starting with the first steam engines onto todays electrified railway tracks, the need and the demand for communication and signalling between dispatcher and the running train, as also for the communication between dispatcher and dispatcher has increased exponentially. The ITU Radiocommunication Sector (ITU–R) Working Party 5A (WP 5A) has identified four general categories of railway communication applications (see details in Report ITU–R M.2418-0):

- Train radio for voice and data services between the train and the trackside.
- Train remote as an application e.g. of shunting.
- Train surveillance for monitoring of stations, tracks and passengers.
- Train positioning for the exact determination of the actual train position.

In particular, the last one has been and still is an essential element for the safe operation of trains.

Fail-safe communications

Communication became a not-without-requirement of a railway system to ensure safety of passengers and goods. Signalling and communication between the different parties involved started with simple flags, moving on to trackside signals using a semaphore or light signals to carry the information. Combined with train protection systems operated as an intermitted system or inductive loop system, all kinds of communication systems have to prove their reliability and fail-safe-operation. Some of these train protection systems, date back to the 1920s, and are still in use. However, the trend is to go for higher grades of automation.

In Europe the train management system used today is the ERTMS (European Train Management System). ERTMS is a combination of two elements; a Radio Bearer Service + ETCS (European Train Control system), supporting different levels (1-3) of automation. The radio bearer service used for ERTMS today is the Global System for Mobile Communications — Railway (GSM-R).

Old technology still widely in use

GSM-R is a railway specific derivate of the 2G GSM technology introduced in the late 1990s. While the end of life for GSM-R is expected to be around 2030, GSM-R is still in rollout in Europe. Even old-fashioned analogue radio systems are still widely in use, while in some other regions the trend is moving to mmWave systems to provide high data rates from or towards running trains.

Obsolence of comunication technology — the railway sector's biggest challenge

With the obsolescence of GSM-R as a technology used for train radio, the railway sector is facing one of its biggest challenges ever — the revolution in railway communication. A key element is the digitization of the railway sector, with a move from circuit switched based communication systems towards IP-based systems, allowing the separation of the transport layer and the application layer.

New radio technologies like 4G or 5G, with their IP-based communication, will pave the way towards systems that allow high reliability, high availability, and radio connections with low latency.

Making use of the new possibilities offered by this technology, together with an increased accuracy of train positioning, automatic train operation (ATO), and remote driving, seem to be in reach in the near future.

A future with automatic train operation

ATO will support different grades of automation (GoA 1-4) where GoA 0 represents todays driver-controlled environment, while GoA 4 will be a completely unattended fully autonomic train drive.

Evolved communication systems will also support the virtual coupling of trains, automatic train assembly of cargo trains, foster real-time-way-side-monitoring, and train positioning. This change will also allow a more flexible train operation system by moving away from fixed blocks, where only one train is allowed at a time, to the creation of a safety zone around the moving train. With such a new system the efficiency of a railway track could be increased.

Implementation of the Internet of things (IoT) with a massive number of sensors along the track and on the train will enable predictive maintenance. But IP-based technologies bar also a risk — a matter of concern is cybersecurity — which will be one of the major challenges for the future.

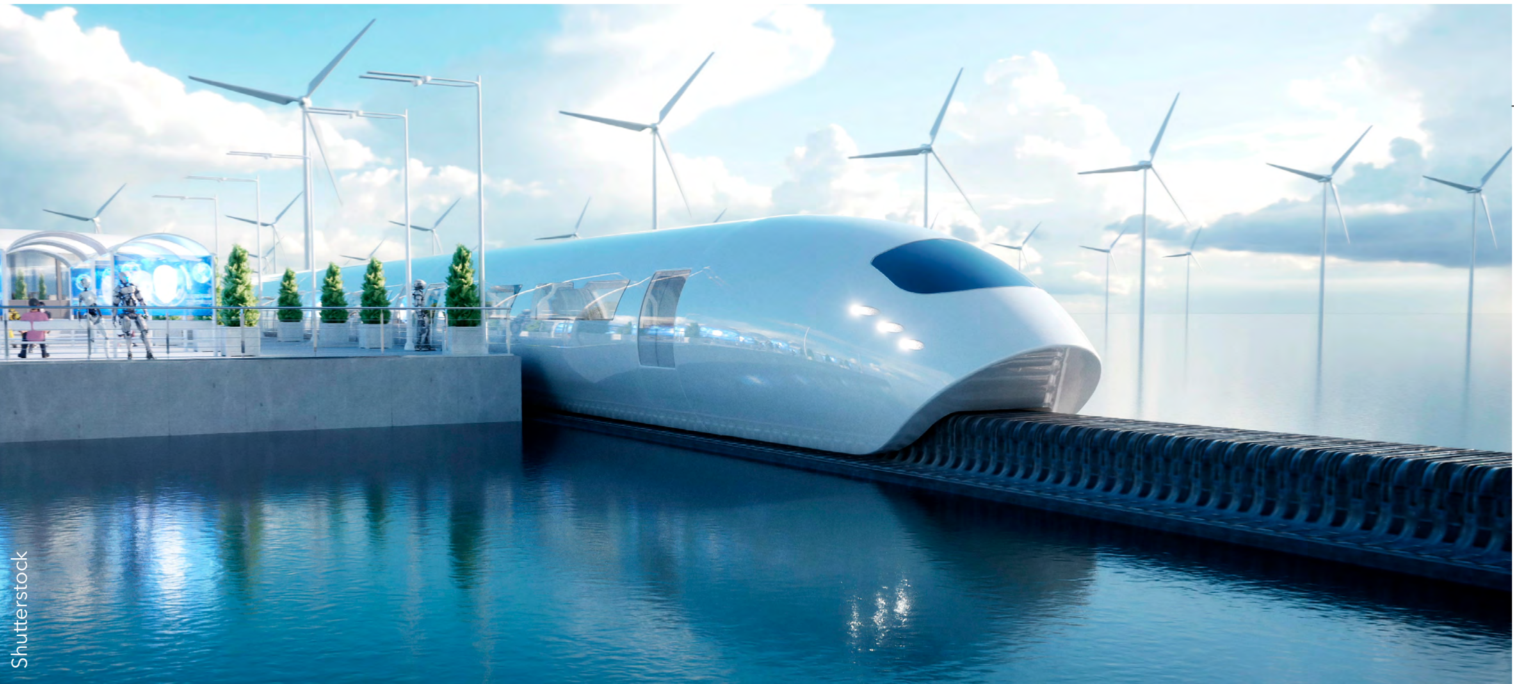
Increasing demand for passenger services

Besides all the operational communication required, there is also an increasing demand for passenger services like web browsing, streaming services, mobile office or video conferences during their travel. Passengers expect an experience that feels like home while travelling in a train, starting with bandwidth of a few hundred Mbit today ending in the Gbit range in the near future. Ensuring an environment which is free from harmful interference inside and outside the trains will be an additional challenge, in particular when similar technologies are used in adjacent frequencies.

Spectrum — essential for future railway systems

Finally, future railway (communication) systems are not only limited to satisfy the demand of higher efficiency and mobility in the gigabit society, but will also facilitate ambitious climate targets. An essential element to enable these objectives to be attained is spectrum. Criteria such as social, socio-economic and climate-friendly aspects should be taken as a basis for the identification of such sufficient spectrum.

Disclaimer: The views and opinions expressed in this article are those of the author and do not necessarily reflect the views of Deutsche Bahn AG.



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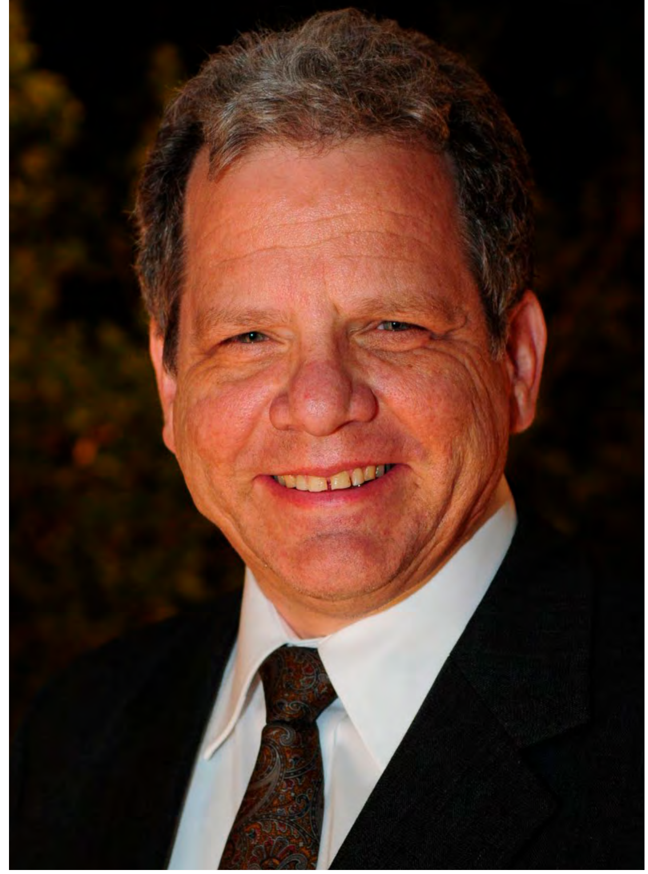


5G for the future railway mobile communication system

David Rothbaum

Director of Business Development, Ericsson

The railway environment has one of the most challenging sets of communication requirements. Railways require connectivity at speeds up to 500 kilometres per hour (km/h), while travelling in cuttings and tunnels with typically poor radio frequency (RF) coverage. They also require very high availability reaching, or exceeding 99.999%, due to the need to control driverless trains. In addition, to improve security and safety, real time passenger surveillance and front-looking obstacle detection cameras add the requirement of high uplink throughput capacity.

ITU has published recent studies of these railway requirements in Report ITU–R M.2418-0 (11/2017) *"Description of Railway Radiocommunication Systems between Train and Trackside (RSTT)"*. In addition, Report ITU–R M.2442-0 (11/2018) *"Current and future usage of railway radiocommunication systems between train and trackside"* provides a comprehensive survey of spectrum usage and requirements of railways globally.

> *"Railways hope to deploy FRMCS — the successor to the current GSM-R technology."*
>
> David Rothbaum

5G new radio for railway

In railways, the radio tower site-to-site distance requires special attention. This distance varies depending on the type of area (rural or urban) and is determined by the cell edge conditions of the RF signal. Railways hope to deploy the Future Railway Communications System (FRMCS (see video)) – the successor to the current Global System for Mobile Communications – Railway (GSM-R) technology, at the current GSM-R inter-site distance, to reuse the site infrastructure.

The European Commission is currently exploring 919.4–921 MHz downlink and 874.4–876 MHz uplink as an interim spectrum adjacent to the GSM-R band as well as the 1900–1910 MHz TDD (3GPP Band 39).

The 900 MHz band interim spectrum would evolve to a 919.4–925 MHz downlink and 874.4–925 MHz uplink once GSM-R vacates its current band (876–800 MHz and 921–925 MHz).

These proposed bands are adjacent to those used by legacy mobile network operators and therefore may need to employ power restrictions to avoid adjacent channel interference and receiver blocking. The European Commission is currently studying the coexistence requirements with adjacent mobile network operator spectrum.

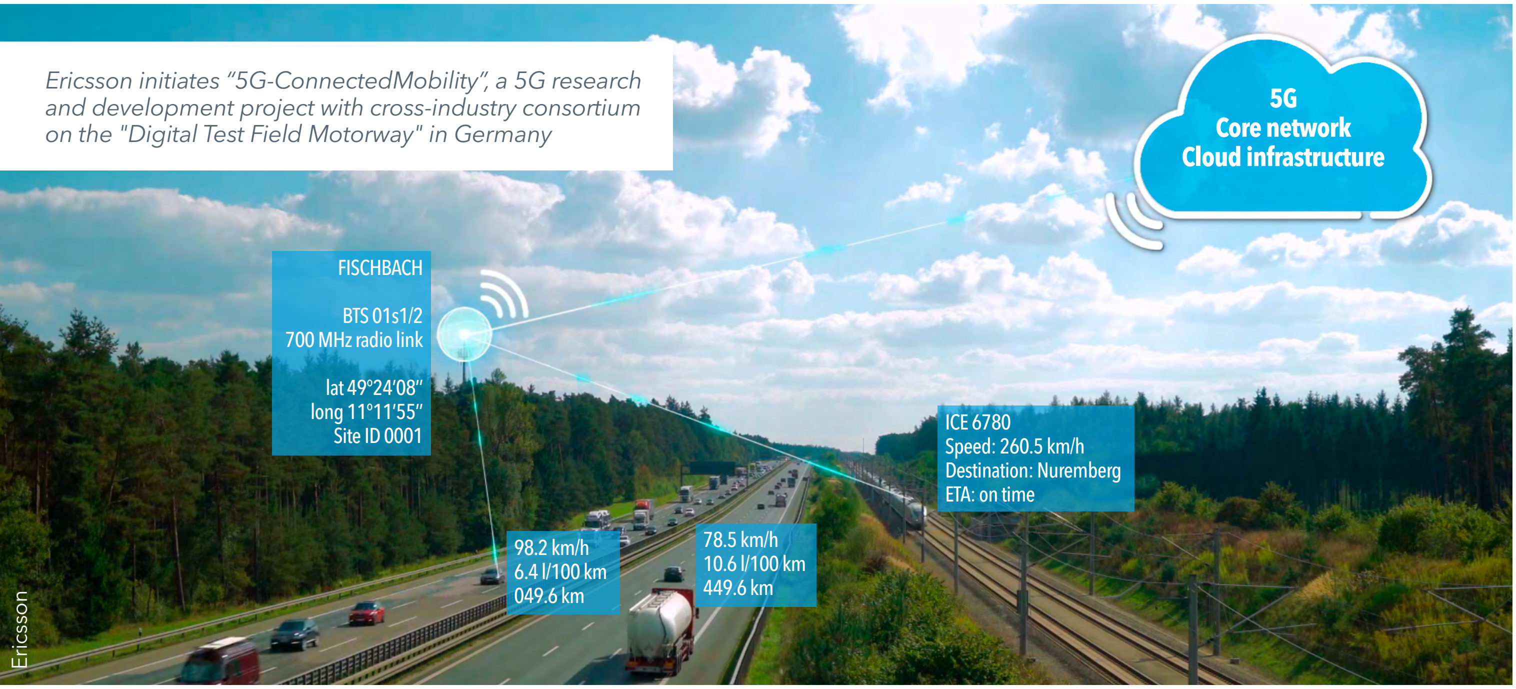
Video passenger surveillance and IoT (Internet of Things) train telemetry applications put a heavier demand on uplink than downlink throughput as opposed to typical mobile broadband applications which are more weighted to downlink throughput demand. A time-division duplexing (TDD)-based railway access network can be configured to deliver the uplink/downlink ratio which best fits the railway needs.

Ericsson is currently performing a simulation study of multiple-input and multiple-output (MIMO), and beam forming techniques at the proposed 900 MHz and 1900 MHz bands, to determine the edge throughput that a high-speed train would experience at cell edge, using Report ITU-R M.2135-1 (12/2009) modelling techniques.

The results of this study will be shared with the railway industry later this year. Early results show promise of 1900 MHz delivering edge throughputs with 10 MHz of bandwidth exceeding an long-term evolution (LTE) band limited to 1.4 MHz bandwidth adjacent to GSM-R.

Network slicing in a railway environment

In a railway environment, spectrum resources dedicated exclusively to railways may be insufficient, or unavailable. Under these circumstances communication services may need to be obtained from commercial mobile network operators.



Ericsson initiates "5G-ConnectedMobility", a 5G research and development project with cross-industry consortium on the "Digital Test Field Motorway" in Germany

The 5G network architecture provides a network-slicing feature which allows railways to obtain a slice of network resources at a guaranteed service and quality level. Network slicing allows the creation of a logical partition of a third-party network with appropriate isolation, resources and optimized topology to serve the railways specific connectivity needs. A network slice can be allocated to an individual railway application requiring unique latency, throughput or availability characteristics.

The 5G network architecture supports end-to-end network slicing. This would require an on-board user equipment (UE) gateway modem/router to route the on-board application service flow to the most appropriate network slice. The Session Management Function (SMF) in the 5G core allows multiple SMF instances to be associated with one UE, one for each network slice. This would enable railway applications to be assigned the network slice at the UE embedded in the on-board gateway.

Ericsson is currently engaged with Deutsche Bahn in validating network slicing along the A9 railway and highway corridor between Munich and Nuremberg in the 5G Connected Mobility trial (see photo above).

Bearer flexibility and quality of service

In the legacy GSM-R system only the GSM-R bearer is capable of transporting the voice and data on-board applications to the ground. The railway industry has decided to overcome this constraint by introducing the flexible bearer requirement. Bearer flexibility is the ability of the on-board UE to select an appropriate bearer based on the application QoS requirements from a set of 3rd Generation Partner Project (3GPP) or non-3GPP bearers. The 3GPP bearers could be one of a set of radio bearers using the railway allocated spectrum, or non-3GPP bearers, such as Wi-Fi, or satellite connections from train to ground.

The 5G core architecture is well suited to fulfil the bearer flexibility requirement. The Access and Mobility Management Function (AMF) is designed to handle UE-related functions among a multitude of radio access technologies (RATs), including non-3GPP RATs.

This would allow railways to utilize the IEEE 802.11 WLAN (wireless local area network) access where feasible. For example, a train parked at a depot could utilize WLAN access to upload massive amounts of CCTV (closed-circuit television) passenger surveillance videos stored on the train without loading its LTE (long-term evolution) or NR (new radio) spectrum.

During long train dwell times at stations the train telemetry data stored in the Train Control Management System could also be uploaded via WLAN connected to the 5G core.

In many countries railways operate in rural areas where the amount of railway traffic does not justify building a dedicated access network nor is there adequate mobile network operator coverage to fall back on. In these cases, satellite access is the most feasible option.

In addition, should a crisis occur such as a significant earthquake, a flood, or a war, elements of the RATs could be destroyed. By temporarily using a satellite access connected to a geo-redundant or distributed 5G core, railways would be able to continue to operate throughout the crisis.

The key goal in Quality of Service (QoS) for railway is the assignment of appropriate QoS policies for each service flow based on the underlying application requirement. The 5G QoS policy framework has been designed to allow for a service flow treatment of different data packets. It also provides more flexible and independent QoS handling at each of the core, RAN (radio access network) and UE layers of the network. The 5G application detection mechanism ensures that each service flow can be assigned its own prioritization, pre-emption and arbitration rules and can be gated for only authorized traffic.

The 5G policy framework only communicates its policy decision to end points via applications functions. In the case of the Future Railway Mobile Communication System (FRMCS), this would be an MCX (Mission Critical to X) server.

Therefore, each FRMCS user requiring a notification of pre-emption would need to be registered on the MCX server. However, autonomous FRMCS applications would have a deterministic high-priority arbitration rule applied to them like the ultra-reliable-low-latency devices introduced in 5G. These devices would always have prioritized access to resources. As such, there would be no need for them to use the MCX framework.

This QoS framework has an additional significant feature related to the on-board railway modem/router gateway UE. The 5G core can provide policy information from the policy control function directly to the UE. In this manner, each on-board application can be routed to its own service flow based on the 5G core policy.

Ericsson, together with major European railways, is engaged in defining the 5G end-to-end architecture best serving the railways' needs. Ericsson also deploys railway applications in its Aachen research and development facility to validate the various 5G architecture models in simulated railway environments.

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