Radiocommunication Study Groups

GENERAL ASPECTS

ITU-APT Foundation of India (IAFI)

PRELIMINARY DRAFT NEW EDITION OF THE HANDBOOK ON GLOBAL TRENDS IN INTERNATIONAL MOBILE TELECOMMUNICATIONS (IMT)

Handbook on Global Trends in IMT

1   Background

ITU-R Working Party (WP) 5D is working on a new edition of the Handbook on global trends in International Mobile Telecommunications (IMT). It is expected that this could be finalized in the 40th meeting of WP 5D

2   Proposal

In this contribution, we are proposing that some editorial modifications to section 2.6.4, section 6.4 the draft working document of the Handbook. Further it is proposed that the list ITU-R references including Reports and Recommmnedations relating to IMT in Annexes B and G should be reconciled and updated.

Attachment 1: Editorial updates to the draft document WP 5D/886 H3-N3.11

Attachment 2: Draft liaison statement to ITU-T

Handbook
on
Global Trends in IMT

Edition of [2022]

ITU-R

Foreword

This International Telecommunication Union (ITU) Handbook on Global Trends in International Mobile Telecommunication (IMT) is a success story of international cooperation amongst qualified and skilled experts in the field of advanced mobile communications and regulations representing national regulatory agencies, mobile operators and major players in the IMT industry.

Recognizing the rapid progress of IMT, this Handbook does not necessarily contain all aspects of the future development of IMT. However it provides a useful guide to the main features of the current systems and the trends towards the future. The readers are encouraged to check the latest version of the Handbook's references.

We acknowledge with special thanks the helpful contribution to the discussions of all participants to ITU-R Working Party 5D and those who have provided useful elements such as data and system parameters of existing IMT systems.

The development of this Handbook has also benefited from the numerous contributions by the participants in the various ITU groups involved, in particular the groups responsible for the ongoing maintenance and updating of the information in their area of responsibility: ITU-R WP 5D (Radio aspects), ITU-R WP 4B (satellite aspects), ITU-T SG 13 (core network aspects), and ITU-D (developing countries aspects).

We believe that this Handbook, together with other ITU publications, will serve as practical tool to assist Administrations and other stakeholders in their endeavours to further develop their IMT networks for the provision of Mobile broadband services.

Table of Contents

1   Introduction

This Handbook identifies International Mobile Telecommunications (IMT) and provides the general information such as service requirements, application trends, system characteristics, and substantive information on spectrum, regulatory issues, guideline for the evolution and migration, and core network evolution on IMT.

This Handbook also addresses a variety of issues related to the deployment of IMT systems.

1.1   Purpose and scope

The purpose and scope of this Handbook is to provide general guidance to ITU Members, network operators and other relevant parties on issues related to the deployment of IMT systems to facilitate decisions on selection of options and strategies for introduction of their IMT-2000, IMT-Advanced and IMT-2020 networks.

The Handbook focuses on the technical, operational and spectrum related aspects of IMT systems, including information on the deployment and technical characteristics of IMT as well as the services and applications supported by IMT.

This Handbook updates previous information on IMT-2000 and IMT-Advanced. It also includes new information on IMT-2020 from Recommendation ITU-R M.2150. In addition, the work from Report ITU-R M.2243 – Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications, is referenced regarding any future considerations that are identified. This Handbook has been and will continue to be a collaborative effort involving groups in the three ITU Sectors with ITU-R Working Party 5D assuming the lead, coordinating role and responsibility for developing text for the terrestrial aspects; with ITU-R Working Party 4B responsible for the satellite aspects, ITU-T Study Group 13 responsible for the core network aspects and ITU-D Q.25/2 responsible for the developing countries aspects.

Special attention has been given to needs of developing countries responding to the first part of Question ITU-R 77/5 which decides that WP 5D should continue to study the urgent needs of developing countries for cost effective access to the global telecommunication networks.

This Handbook also includes summary of deliverables and on-going activities of WP 5D in order to provide an update for countries which are not able to attend WP 5D meetings.

1.2   Vocabulary of key terms used in this Handbook

Broadband Commission	The Broadband Commission for Digital Development is composed of the International Telecommunication Union (ITU) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). The Commission embraces a range of different perspectives in a multistakeholder approach to promoting the roll-out of broadband, as well as providing a fresh approach to UN and business engagement.
IMT	International Mobile Telecommunication (IMT) encompasses both IMT-2000 and IMT-Advanced collectively based on Resolution ITU-R 56
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radiocommunication Sector
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector

ITU-D	International Telecommunication Union – Telecommunication Development Sector
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2

2   Usage trends and service requirements

2.1   Introduction

In order to understand current trends in IMT, it is important to consider and understand how mobile broadband is being used and for what purposes (including key features of IMT technologies), and any special requirements of developing countries. Together, these topics provide a foundation upon which to build a stronger understanding of the topics discussed in subsequent sections of this Handbook. The following sections discuss application trends (such as mobile Internet usage, video traffic, social networks, and machine-to-machine traffic); market trends in traffic and devices; key features of each iteration of IMT technologies; the use of IMT to serve urban, rural and remote areas; and considerations for developing countries, such as barriers to access.

2.2   Usage trends

2.2.1   Mobile Internet usage

Mobile Internet usage has been growing rapidly on a worldwide basis over the past years. While the state of mobile Internet usage can be measured in several ways, the growth – and projected growth – is perhaps most striking when considering mobile data traffic volumes and data speeds.

Ericsson, for example, has quantified the total mobile network traffic to 58EB per month at the end of 2020. The total mobile network traffic is forecast to exceed 300EB per month in 2026[1]. Adding some perspective to that figure, the authors noted that the increase in mobile data traffic from the second quarter of 2013 to the third quarter exceeded the total monthly mobile data traffic estimated in the fourth quarter of 2009. In the latest one-year period of Ericsson's analysis, mobile data traffic grew by approximately 80 percent.[2].

In another comparison, the Groupe Spéciale Mobile Association (GSMA) noted that more mobile traffic was generated in 2012 than in all other years combined[3]. Looking ahead, mobile devices are expected to continue to outpace other sources of Internet usage. For example, when considering the sources of IP traffic over the world's telecommunications networks,[4] Cisco forecasted that the number of devices connected to IP networks will be more than three times the global population by 2023. There will be 3.6 networked devices per capita by 2023, up from 2.4 networked devices per capita in 2018.t[4].

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[1] Ericsson, *Ericsson Mobility Report* (2021) at 10, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

[2] Ericsson, *Ericsson Mobility Report* (2021) at 11, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

[3] GSMA, *The Mobile Economy 2021*, available at https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/07/GSMA_MobileEconomy2021_3.pdf

[4] Cisco, *Cisco Annual Internet Report (2018–2023)*, available at https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

Globally, the total number of Internet users is projected to grow from 3.9 billion in 2018 to 5.3 billion by 2023 at a CAGR of 6 percent. In terms of population, this represents 51 percent of the global population in 2018 and 66 percent of global population penetration by 2023.. This rate would be three times faster than fixed traffic over the same period. Smartphone technology and adoption have progressed rapidly in the last several years, providing users with robust, mobile access to broadband services, and comprising the category that will likely make up the bulk of mobile broadband subscriber devices.

According to Ericsson's most recent analysis, smartphones accounted for approximately 55 percent of all mobile handsets sold in the third quarter of 2013, while they made up approximately 40 percent of all handsets sold in all of 2012[5]. The analysis also indicated that there is significant room for additional growth, with only 25 to 30 percent of mobile phone subscriptions associated with smartphones.

There will be an additional 1.6 billion smartphone connections by 2025, bringing the overall adoption level to over 80% of total mobile connections.

One analysis indicated that while approximately 5 percent of smartphones were LTE-enabled in July 2011, by August 2013, more than 30 percent could take advantage of LTE networks[6]. Along with the growth in smartphones, the speed of mobile connectivity continues to increase across the world as well as networks and devices implement the latest technologies, such as LTE. Cisco noted thatthe average mobile network connection speed was 13.2 Mbps in 2018 and will be 43.9 Mbps by 2023. . There are around 8 billion mobile subscriptions. The analysis estimated that this figure will increase to 8.8 billion by the end of 2026, of which 91 percent will be for mobile broadband Average smartphone data rates are forecast to triple by 2017, reaching 6.5 Mbps[7]. There is anecdotal evidence to support the idea that usage increases when speed increases, although there may be a delay between the increase in network and device speed and the resultant increased usage, potentially a lag of several years.

2.2.2 Mobile software application offerings (Apps)

A key driver of mobile data usage has been the rapid proliferation of software applications, commonly known as "apps," for use on smartphones and other mobile devices. Taking into consideration the two largest app ecosystems, there were approximately 900 000 apps available for iOS (the operating system that powers Apple's iPhone, iPad and iPod devices) and approximately 800 000 apps available for Android (the operating system for a wide range of mobile handsets and tablet devices)[8]. There is likely substantial overlap between the ecosystems, with many developers releasing applications for both operating systems in order to reach the largest potential customer bases. Both ecosystems have seen fairly steady growth in recent years, although the rate of growth for Android applications has increased recently. Application download estimates vary widely.

ABI Research estimated that there would be a total of 56 billion smartphone apps downloaded in 2013 (including not just iOS and Android, but also Windows Phone and Blackberry), while Portio

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[5] Ericsson, *Ericsson Mobility Report* (2021) at 4, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

[6] Global Mobile Suppliers Association, "LTE: user device segmentation: 2011-2013," (2013), available at http://www.gsacom.com/downloads/pdf/LTE_user_device_segmentation_250813.php4.

[7] Cisco,Cisco Annual Internet Report available at https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

Research estimated that 82 billion apps would be downloaded worldwide in 2013. Regardless of the exact number, it is worth noting that this mobile app downloads are a relatively new phenomenon, having begun in earnest with the launch of Apple's App Store in 2008.

Similarly, the number of apps downloaded has increased rapidly. For example in 2010, an estimated five billion iOS apps and 289,000 Android apps were downloaded, as compared to an estimated 48 billion iOS apps and 50 billion Android apps in early 2013. Applications are generally grouped into certain categories, with analysts parsing network traffic to identify the amount of traffic generated by each group, as well as to forecast future traffic patterns. Ericsson's breakdown of current mobile application traffic percentages and a forecast for traffic in 2019 are presented in Figure 1.

In particular, Ericsson expected that video content would continue to drive mobile data usage, representing more than 50 percent of traffic by 2019.

Source: Ericsson

As mobile network speeds and capacity continue to increase, mobile software applications are expanding to take advantage of both. A GSMA and A.T. Kearny analysis forecasts that mobile data traffic will grow at a CAGR of 66 percent between 2012 and 2017, reaching a monthly rate of 11 156 petabytes[9]. The GSMA analysis predicted that several services will experience CAGR of more than 30 percent over the 2012-2017 period: VoIP (34 percent), gaming (62 percent), M2M (89 percent), file sharing (34 percent), data (55 percent) as well as video (75 percent). The following sections examine some of these important drivers in more detail.

2.2.3 Video traffic

As noted in section 2.2.1, mobile data traffic has been growing at a rapid pace, and is expected to continue to do so. The major driver of this growth is expected to be mobile video, which has been predicted to account for more than 7 000 petabytes of monthly data traffic by 2017[9]. Ericsson forecasted that mobile video traffic will increase at an average annual rate of 55 percent through 2019 Video traffic currently accounts for 66 percent of all mobile data traffic, a share that is forecast to increase to 77 percent in 2026.[10].

As a result, according to one analysis, as many as 41 percent of people between the ages of 65 and 69 stream video content over fixed or mobile networks on at least a weekly basis[12]. One possible development that may drive additional mobile video traffic is gaming. While currently, the data traffic volumes and speed requirements of many single or multi-player games available on mobile devices are relatively low, there is some expectation that this situation will change in the future[13]. As more games adopt elements such as multi-player features, high-definition content and video streaming, gaming may become a more important driver of video traffic.

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[9] GSMA, *The Mobile Economy 2021*, available at https://www.gsma.com/mobileeconomy/wp-content/uploads/2021/07/GSMA_MobileEconomy2021_3.pdf

[10] Ericsson, *Ericsson Mobility Report* (2021) at 13, available at https://www.ericsson.com/en/mobility-report/reports/june-2021 .

[12] Ericsson, *Ericsson Mobility Report* (2021) at 13, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

[13] Ericsson, *Ericsson Mobility Report* (2021) at 26, available at https://www.ericsson.com/en/mobility-report/reports/june-2021 .

2.2.4 Social networks on mobile

Currently, social networking is estimated to account for approximately 10 percent of total mobile data traffic[12]. Ericsson estimated that this share will remain constant through 2019, although social networking usage increasingly will include more data-rich content, such as photographs and video[13]. When considering how people use their mobile devices, social networking is already the second-largest generator of data traffic volume. Between 2012 and 2013, Ericsson noted an increase in the percentage of social networking traffic on smartphones[14].

Importantly, the use of mobile handsets for social networking far exceeds such use on tablets and laptops, where the percentage of mobile data traffic generated by social networking is below five percent, as shown in Figure 2.

FIGURE 2

Application mobile data traffic volumes by device type (2013)

Using social networking on smartphones, and watching video on tablets and mobile Pcs has increased since 2012
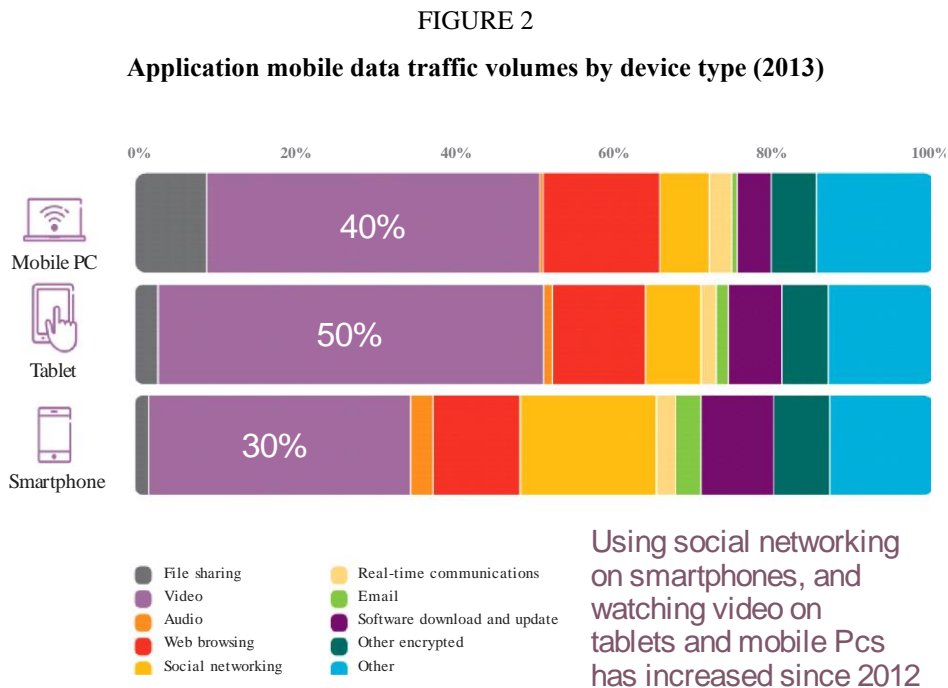
Global Trends-02

Source: Ericsson

Considering how smartphone users spend time on their devices, Google data from 41 countries indicated that more than half of all smartphone users use social networking at least monthly, and more than 25 percent do so daily[15]. In 27 of those countries, more than 75 percent of smartphone users access social networks at least monthly. An Ericsson analysis showed that social networking is the most popular activity among iOS and Android smartphone users in the United States of America, accounting for 13.1 hours per month[16]. The next most popular smartphone use in this analysis was entertainment, which was responsible for 8.5 hours of use per month.

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[14] Ericsson, *Ericsson Mobility Report* (2021) at 15, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

[15] Google, "Our Mobile Planet", available at http://www.thinkwithgoogle.com/mobileplanet/en/.

[16] Ericsson, *Ericsson Mobility Report* (2021) at 26, available at https://www.ericsson.com/en/mobility-report/reports/june-2021 .

2.2.5 Machine-to-machine traffic

As mobile network coverage and capacity has expanded, and the cost of embedding connectivity into various types of equipment has declined, the number of Internet-connected devices has grown rapidly. Many of these devices are expected to continuously monitor some sort of situation or status, report information to users, and/or communicate with each other. Depending on the definition used, M2M communications can include a wide range of devices, such as remote sensors, "smart" electricity grids, Internet-connected appliances and automobiles, and manufacturing equipment, just to name a few.

M2M connections will be half of the global connected devices and connections by 2023. The share of Machine-To-Machine (M2M) connections will grow from 33 percent in 2018 to 50 percent by 2023. There will be 14.7 billion M2M connections by 2023[17].

Within the M2M connections category (which is also referred to as IoT), connected home applications will have the largest share and connected car will be the fastest growing application type. Connected home applications will have nearly half or 48 percent of M2M share by 2023 and Connected car applications will grow the fastest at 30 percent CAGR over the forecast period (2018–2023).

2.2.6 Other drivers of future data traffic

The demand for mobile cloud services is expected to grow exponentially since the users are increasingly adopting more services that are required to be accessible. The consequence is that the volume of mobile content they generate cumulatively grows. Multimedia services captured on mobile devices will overwhelmingly carry the greatest cloud computing and storage demand and the average size of these media files will grow substantially as camera pixel resolution continues to increase (ARC Chart[21] predicts that mobile-generated content will consume 9 400 PB of cloud services by 2015).

Furthermore, cloud services are getting a lot of attention since, among other benefits, they save costs for enterprises. These cloud services require guaranteed data communication between the clients and the connected data centres hosting IT servers. As the number of mobile users connecting through the mobile network to the cloud increase, the mobile data traffic will continuously grow.

As mobile software applications advance due to increasing processing power, mobile data traffic is expected to increase[22].

The cloud architecture is a relevant evolution of the provisioning of digital services and applications that has to be considered when planning for the evolution of IMT technologies. Economic underpinnings of all these technological developments is the ability to move data across borders to facilitate a number of key functions such as; communication, information, content, e-commerce, M2M, etc. But even more the realities behind the productions of mentioned functions e.g. the presence of global value chains must be recognized. This means that in the B2B market, today's complex ICT systems that are required to realize these new technologies and functions rely on the ability of companies to develop, produce, integrate, manage and support these systems from

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[17] Cisco Annual Internet Report (2018–2023) White Paper, available at
https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

[21] ARC Chart Research Report on the mobile cloud: Market analysis and forecasts, June 2011.

[22] Report ITU-R M.2243 – Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications, section 3.10.

multiple territories and hence the ability to collaborate and exchange data across territories is absolutely essential.

2.3 Market trends

2.3.1 Global IMT subscriber information from 2020 to 2026

According to the ITU, the number of active mobile-broadband subscriptions stood at 75 per 100 inhabitants in 2020. [23].

The number of active mobilebroadband subscriptions per 100 inhabitants continues to grow strongly, with an 18.4 per cent year-on-year growth. Eventhough, annual growth has been slowing down gradually since 2017, and 2020 coverage is only 1.3 percentage points higher than 2019.

The ITU also noted in 2013 that the number of mobile broadband subscriptions in developing countries had more than doubled since 2011, from 472 million to 1.16 billion, surpassing the number of subscriptions in developed countries[24].

There is still a substantial penetration gap between the developed and developing countries, however. According to the ITU, there is 122 active mobile-broadband subscriptions of every 100 developed country inhabitants, as compared to 75 of every 100 inhabitants in developing countries[24].

As noted by the Broadband Commission in its 2013 Report, *The State of Broadband 2013: Universalizing Broadband*, mobile broadband subscriptions surpassed fixed broadband subscriptions in 2008, and have shown an annual growth rate of approximately 30 percent[25]. That classifies mobile broadband as having, according to the Broadband Commission, the highest growth rate of any ICT, exceeding fixed broadband subscriptions by a ratio of 3:1 (up from 2:1 in 2010).

When considering the growth of IMT subscriptions, rapid growth is expected over the next several years. Ericsson data, illustrated in Figure 3,indicated that the majority of subscriptions were LTE devices in North America and Western Europe in 2013, while the majority of mobile subscriptions will be comprised between LTE and 5G devices in all regions of the world by 2026. [26].

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[23] ITU, "Measuring digital development: Facts and Figures "" (2020) at 4, available at https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2020.pdf

[24] ITU, "Measuring digital development: Facts and Figures "" (2020) at 4, available at https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019_r1.pdf

[25] Broadband Commission, *The State of Broadband: Tackling Digital Inequalities* (2020) at 12, available athttps://www.broadbandcommission.org/publication/the-state-of-broadband-2020/ .

[26] Ericsson, *Ericsson Mobility Report:* (2021) at 9, available at https://www.ericsson.com/en/mobility-report/reports/june-2021

FIGURE 3

Mobile subscriptions by region and technology, 2020 and 202619
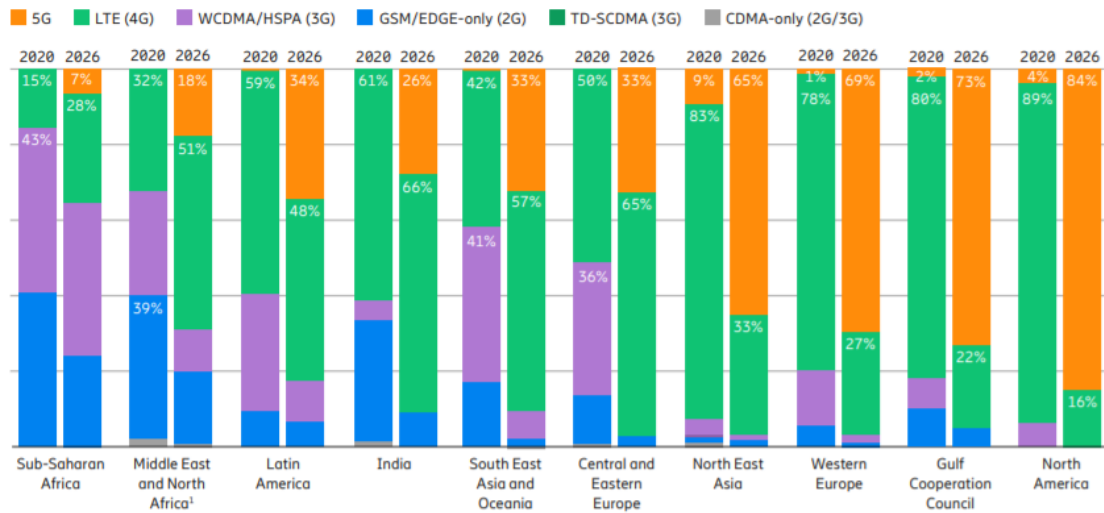
Source: Ericsson

2.3.2   Device Type

As mobile broadband connectivity continues to spread and also to increase its capacity and speeds, a growing number of device types have been developed to serve differing user needs. When considering devices supporting 5G, for example, the Global Mobile Suppliers Association (GSA) announced thatthe number of 5G devices has continued to grow, reaching 873, an increase of 24.2% over the first quarter of 2021. Of these announced 5G devices, 63.8% are understood to be commercially available. The number of commercial 5G devices has grown by 29.2% over the last quarter, to reach 557 commercial 5G devices.[27]. Tablets and personal hotspots and routers are also fast-growing segments of the device ecosystem.

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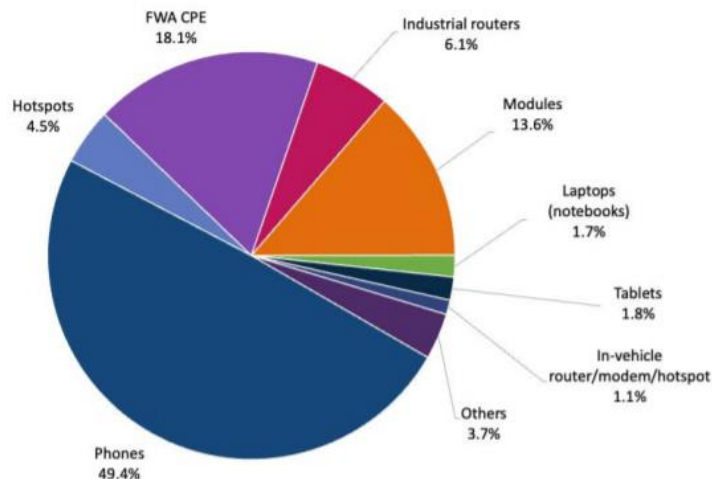
[27] Global Mobile Suppliers Association, 5G Devices: Executive Summary – July 2021at 2, available at https://gsacom.com/reports/GSA-5G-Device-Ecosystem-ES-July-2021.pdf

According to GSMA, by the end of 2020, 5.2 billion people subscribed to mobile services, representing 67% of the global population. Adding new subscribers is increasingly difficult, as markets are becoming saturated and the economics of reaching rural populations are becoming more difficult to justify in a challenging financial climate for mobile operators. That said, their analysis estimated thatthere will be nearly half a billion new subscribers by 2025, taking the total number of subscribers to 5.7 billion (70% of the global population)[28].

[29].

The growth in smartphone subscriptions was forecast to come primarily as users exchange their basic phones for smartphones in Africa, Asia and the Middle East over the next several years, due in part to the availability of lower-cost devices. Laptops, tablets and mobile router subscriptions will continue to grow as well, from 300 million in 2013 to 800 million in 2019. Ericsson also predicted significant regional differences, with smartphones comprising almost all handsets sold in Western Europe and North America in 2019, compared to 50 percent of handset subscriptions in the Middle East and Africa[28].

2.3.3 Network and user experience improvement

As mobile data traffic demand continues to grow, mobile network operators are spending heavily to upgrade their networks in order to increase their capacity and improve the user experience. One analysis estimated that operators would spend USD 8.7 billion on LTE network upgrades alone in 2012, rising to USD 24 billion in 2013 and USD 36 billion by 2015[30].

One of the most commonly considered measures of user experience is average mobile network speed. According to Cisco, speeds will increase across all regions and all device types between now and 2017[31]. Globally, the average mobile network connection speed in 2012 was 526 kbps. This average will grow at a CAGR of 49 percent, and will exceed 3.9 Mbps in 2017.

. Across all regions, Cisco estimates that average mobile data speeds will increase at a CAGR of at least 36 percent through 2017, with the Middle East and Africa increasing at a CAGR of 68 percent.

IMT technology has become widespread in global mobile networks. With the commercialization of LTE technology in recent years, operators are rapidly moving to upgrade their networks.By the end of 2026, 5G will account for 40.8% of the global market (at 4.62 billion subscriptions), although LTE will still represent the biggest share of the market at 46.8% of all global mobile subscriptions.The evolution of IMT systems has continuously increased the data rates available to mobile broadband users. Technologies have continued to increase peak data speeds with each iteration and new technology.

Advances in technology alone, however, sometimes cannot support the rapid growth rates that are being seen in mobile data use. This is particularly true in urban areas around the world. Thus, operators and regulators worldwide are trying to make additional spectrum available for mobile

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[28] GSMA, *The Mobile Economy 2015*, available at http://www.gsmamobileeconomy.com/GSMA_Global_Mobile_Economy_Report_2021.pdf.

[29] Ericsson, *Ericsson Mobility Report* (2021) at 7, available at https://www.ericsson.com/en/mobility-report/reports/june-2021 .

[31] Cisco Annual Internet Report (2018–2023) White Paper, , available at https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

broadband, particularly by making new bands of spectrum available. For example, the transition from analogue to digital television broadcasting can result in a "digital dividend" of spectrum that was formerly used for broadcasting but that now can be made available for other uses. Most countries around the world have either started a process to make that spectrum available for mobile broadband or are planning to do so. The majority of such transitions are expected to be completed in the next 10 years.

2.3.4 Policy initiatives to promote mobile broadband

Governments and multilateral organizations are taking a variety of approaches to promote mobile broadband such as the development of National Broadband Plan. While each country faces unique challenges to increasing mobile broadband adoption, certain general trends or approaches can be applied in many cases. Mobile broadband initiatives are often developed as subsets of plans intended to increase broadband adoption more generally. As such, policy approaches that may improve mobile broadband adoption may closely track those approaches employed to increase fixed broadband adoption.

In other cases, as in many developing countries, mobile broadband is the primary (or only) broadband option available to many individuals and communities. Policy approaches intended to increase mobile broadband supply can include:

– setting concrete, measurable objectives for improving the supply of broadband through infrastructure build-out, including deployment of and upgrades to mobile networks;

– ensuring availability and efficient use of spectrum for mobile services, including flexible spectrum use;

– ensuring competitive, efficient and transparent markets;

– ensuring equitable access to broadband for all; and

– encouraging investment in mobile networks, services and applications.

One of these approaches is to promote the deployment of mobile networks operating in frequency bands below 1 GHz, as the main solution to facilitate provision of broadband mobile services in unserved areas.

Policy approaches intended to increase demand for mobile broadband can include:

– promoting demand for broadband services and applications;

– considering if there is a need for, and an appropriate mechanism to deliver, subsidies for devices and/or service fees, perhaps through a universal access or universal service program;

– making useful information and services available to mobile device users (e.g. m-government, m-health, m-banking); and

– educating users and potential users on the benefits of mobile broadband-enabled services.

The Broadband Commission, while not focusing on mobile broadband specifically, recently proposed policy approaches intended to improve access to broadband that are applicable to the mobile sector. For example, the Commission's 2013 report, as part of its goal of universalizing broadband, suggested establishing adequate spectrum policies and reasonable spectrum allocations, as well as ensuring stable legal and regulatory frameworks to foster and incentivize investments, and creating an environment for sustainable competition[36]. In the same discussion, the report noted

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[36] Broadband Commission, *The State of Broadband 2013: Universalizing Broadband* (2013) at 40, available at http://www.broadbandcommission.org/Documents/bb-annualreport2013.pdf.

the importance of establishing a national broadband plan to guide broadband development. Among the other Broadband Commission policy recommendations applicable to mobile services are to focus on making broadband affordable and to improve penetration, which will go hand-in-hand.

The first Broadband Commission report, *A 2010 Leadership Imperative: The Future Built on Broadband*, noted among its recommendations the need for national policy objectives to include the provision of broadband-enabled services and applications for vulnerable, disadvantaged and remote populations, among others[37]. Particularly with respect to remote populations, mobile technology provides a key means – and perhaps the only economically feasible means – by which to reach these groups.

2.4 Key features of IMT

2.4.1 Key features of IMT-2000

Key features of IMT-2000 are:

– high degree of commonality of design worldwide;
– compatibility of services within IMT-2000 and with the fixed networks;
– high quality;
– small terminal for worldwide use;
– worldwide roaming capability;
– capability for multimedia applications, and a wide range of services and terminals.

Recommendation ITU-R M.1457 identifies the IMT-2000 terrestrial radio interface specifications. These radio interfaces support the features and design parameters of IMT-2000, including the above mentioned features, such as capability to ensure worldwide compatibility, international roaming, and access to high-speed data services.

2.4.2 Key features of IMT Advanced

Key features of IMT-Advanced are:

– high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost-efficient manner;
– compatibility of services within IMT and with fixed networks;
– capability of interworking with other radio access systems;
– high-quality mobile services;
– user equipment suitable for worldwide use;
– user-friendly applications, services and equipment;
– worldwide roaming capability;
– enhanced peak data rates to support advanced services and applications (100 Mbps for high and 1 Gbps for low mobility)[38].

These features enable IMT-Advanced to address evolving user needs.

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[37] Broadband Commission, *A 2010 Leadership Imperative: The Future Built on Broadband* (2010) at 57, available at http://www.broadbandcommission.org/Documents/publications/Report_1.pdf.

[38] Data rates sourced from Recommendation ITU-R M.1645.

Recommendation ITU-R M.2012 identifies the terrestrial radio interface technologies of IMT-Advanced and provides the detailed radio interface specifications. These radio interface specifications detail the features and parameters of IMT-Advanced, including the above mentioned features, such as the capability to ensure worldwide compatibility, international roaming, and access to high-speed data services.

2.4.3 Key features of IMT-2020

Key features of IMT-2020 are:

–   compatibility of services within IMT and with fixed networks;

–   capability of interworking with other radio access systems;

–   high-quality mobile services;

–   worldwide roaming capability;

–   low to high mobility applications;

–   machine type communications;

–   ultra-reliable and low latency communications;

–   high-quality multimedia applications;

Recommendation ITU-R M.2150 identifies and provides the detailed specifications of the radio interfaces for the terrestrial component of IMT-2020 and provides the detailed radio interface specifications. These radio interface specifications detail the feature and parameters of IMT-2020, including the above mentioned features, such as worldwide compatibility, international roaming, and access to the services under diverse usage scenarios, including enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultrareliable and low latency communications (URLLC).

[2.5   Fixed Wireless Access

As technology has improved, operators have been turning to mobile networks to deliver residential and business broadband services. GSA has undertaken a study to determine the extent and nature of fixed wireless access broadband service availability based on LTE or 5G technologies around the world[39].

Operators worldwide are investing in FWA in the form of lab trials, acquisition of licences, field-based pilot projects, network deployments, or commercial service launches. GSA estimates there are at least 460 operators investing in FWA based on LTE or 5G. Of those, GSA has identified available service offers for FWA using LTE or 5G from 436 operators in 171 countries/territories; that equates to more than half of all operators with commercial LTE or 5G networks worldwide. As a result by 2030 it is expected that 5G FWA subscriptions to approach 130 million with annual revenues of USD 53 billion.]

2.5   Servicing urban, rural and remote areas

A number of Mobile Broadband (MBB) systems and applications, based on different standards, are available and the suitability of each depends on usage (fixed vs. nomadic/mobile), and performance and geographic requirements, among others. In countries where wired infrastructure is not well established, MBB systems can be more easily deployed to deliver services to population bases in dense urban environments as well as those in more remote areas. Some users may only require

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[39] GSA, FWA Global Status Update – June 2021, available at https://gsacom.com/paper/fwa-global-status-update-june-2021/

broadband Internet access for short-ranges whereas other users may require broadband access over longer distances. Moreover, these same users may require that their MBB applications be nomadic, mobile, fixed or a combination of all three.

In sum, there are a number of multi-access solutions and the choice of which to implement will depend on the interplay of requirements, the use of various technologies to meet these requirements, the availability of spectrum (licensed vs. unlicensed), and the scale of network required for the delivery of MBB applications and services (local vs. metropolitan area networks)[40].

2.5 Vertical industries

Verticals are defined as companies, industries and public sector organisations operating in a specific sector. Vertical industries have long relied on various wireless technologies and spectrum bands to support their connectivity needs.

However, the requirements of vertical networks are evolving – most notably from voice to high-speed data. Some verticals want networks that support low power wide area IoT for connecting smart meters and sensors, while others want networks that support very low latencies for advanced manufacturing including robotics. The importance of connectivity has created pressures for wide area coverage (e.g. utilities) and/or highly localised connectivity (e.g. manufacturing plants) as well as high levels of reliability including for safety of life applications (e.g. emergency services, hospitals, etc).

Given the needs of different verticals, there have been efforts to categorise complementary scenarios and specific applications in order to asses the network and spectrum requirements.

2.6 Usage scenarios for IMT-2020 and beyond

IMT for 2020 and beyond is envisaged to expand and support diverse usage scenarios and applications that will continue beyond the current IMT. Furthermore, a broad variety of capabilities would be tightly coupled with these intended different usage scenarios and applications for IMT for 2020 and beyond. The usage scenarios for IMT for 2020 and beyond include:

– Enhanced Mobile Broadband: Mobile Broadband addresses the human-centric use cases for access to multi-media content, services and data. The demand for mobile broadband will continue to increase, leading to enhanced Mobile Broadband. The enhanced Mobile Broadband usage scenario will come with new application areas and requirements in addition to existing Mobile Broadband applications for improved performance and an increasingly seamless user experience. This usage scenario covers a range of cases, including wide-area coverage and hotspot, which have different requirements. For the hotspot case, i.e. for an area with high user density, very high traffic capacity is needed, while the requirement for mobility is low and user data rate is higher than that of wide area coverage. For the wide area coverage case, seamless coverage and medium to high mobility are desired, with much improved user data rate compared to existing data rates. However the data rate requirement may be relaxed compared to hotspot.

– Ultra-reliable and low latency communications: This use case has stringent requirements for capabilities such as throughput, latency and availability. Some examples include wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.

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[40] LMH-BWA.

–   Massive machine type communications: This use case is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delaysensitive data. Devices are required to be low cost, and have a very long battery life.

2.6   Use of IMT for specific applications

In this Handbook, the use of IMT for specific applications is considered. Some other applications can be considered in the future if appropriate.

2.6.1   Use of IMT for PPDR applications

Report ITU-R M.2291 addresses the current and possible future use of international mobile telecommunications (IMT) including the use of long term evolution (LTE) in support of broadband PPDR communications as outlined in relevant ITU-R Resolutions, Recommendations and Reports. The Report further provides examples for deploying IMT for PPDR radiocommunications, case studies and scenarios of IMT systems to support broadband PPDR applications such as data and video. PPDR is defined in Resolution 646 (Rev.WRC-12) through a combination of the terms "public protection radiocommunication" and "disaster relief radiocommunication". The first term refers to "radiocommunications used by responsible agencies and organizations dealing with maintenance of law and order, protection of life and property and emergency situations".
The second term refers to "radiocommunications used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant widespread threat to human life, health, property or the environment, whether caused by accident, natural phenomena or human activity, and whether developing suddenly or as a result of complex, long-term processes".
A number of studies of PPDR radiocommunications have been carried out within the ITU, based on Resolution **646 (Rev.WRC-12)** and Report ITU-R M.2033.

2.6.2   Use of IMT for MTC applications

Report ITU-R M.2440 addresses the technical and operational aspects of terrestrial IMT-based radio networks and systems supporting machine type communication (MTC) applications, as well as spectrum needed, including possible harmonized use of spectrum to support the implementation of narrowband and broadband MTC infrastructure and devices.

Globally, the importance of developing reliable and cost effective MTC solutions for various industries is increasing on a daily basis. Examples of these solutions include smart energy management, agriculture, water management, waste management, health, transportation and utilities that may have a direct impact on social and economic development.

MTC has wide range of narrowband and broadband applications based on each use case. Some use cases of broadband MTC include sensors (including health monitoring as an example), actuators and cameras with a wide range of characteristics and demands. Several use cases for MTC require a narrowband connection as well as wide coverage area and low power consumption.

2.6.3   Use of IMT for audio-visual services

Report ITU-R M.2373 "Audio-visual capabilities and applications supported by terrestrial IMT systems" examines the capabilities of IMT systems to deliver audio-visual services to consumers. A IMT is expected to complement traditional broadcasting systems (cable, satellite or terrestrial delivery) or other broadband services (fixed internet access or RLAN) to satisfy consumer demand for audio-visual services, in particular with respect to personalization, portability, easy to use, and mobility.

Today, audio-visual services over IMT (for both linear and on-demand audio-visual content) represent a small percentage of total audio-visual content consumption; however, it is expected that audio-visual over IMT will increase in the future and that it will be the major traffic contributor in IMT networks. Offering audio-visual services over IMT already contributes to national safety and security, economies and social development by enabling a range of applications, such as social media, distance learning, health and entertainment. Furthermore it could further contribute to the reduction of the digital divide between urban areas and rural areas or certain underserved communities. Socio-economic demands are already driving requirements for access to audio-visual services and applications, for users to experience similar quality of experience (QoE), including coverage and data rates in rural and urban areas.

2.6.4 Use of IMT for transport applications

Report ITU-R M.2441 "Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)" provides information on various use cases and specific applications such as:

- Transportation applications such as Intelligent Transport Systems (ITS), Railways or High Speed Train Communication and Bus/Fleet traffic management

- Utilities such as Smart Grids and Water management

- Industrial automation applications such as Motion control, Mobile control panels with safety functions, Mobile robots, Massive wireless sensor networks, Remote access and maintenance, Augmented reality, Process automation, Flexible, modular assembly area, "Plug and produce" for field devices

- Applications for Remote control of machines such as for high-quality Communication links, Mining applications, Construction sites, Harbours

- Surveying and inspection in Oil and gas fields and Eelctricity distribution

- Electricity

- Healthcare applications such as Remote surgery and Clinical Wearables

- Mobile Health Applications

ITU-R WP 5D is also developing a new Report on use of IMT-2020 for various Industrial, enterprise and societal applications.

2.7 Considerations for developing countries

IMT and mobile phones have long surpassed fixed connections in most developing countries, and many broadband services in developing countries are being delivered by IMT. For some people in developing countries, their first and only access to the Internet will be via an IMT device.

Such connectivity, combined with affordable IMT smart phones, provides opportunities to empower individuals across society. For example, with IMT devices, doctors are remotely monitoring cardiac patients in rural villages; farmers are accessing weather information and sales prices to increase their income and improve their standard of living; women entrepreneurs are lifting themselves out of poverty by harnessing the economic benefits of wireless to start businesses and access banking services; and children everywhere can access educational content in and out of the classroom, 24 hours a day. While we are seeing tremendous benefits in key areas such as education, healthcare and commerce, more needs to be done in many social areas to support development agenda. The IMT smart phone is the most largely implemented technological platform in history, and its potential to significantly improve people's lives is just starting to be realized.

Advantages of M2M (Machine-to-machine) applications and IOT (Internet of things) enabled through IMT networks can also help developing countries bridge the digital divide.

The 2013 Annual Broadband Commission Report (Table 3, Source: Inter-American Development Bank) contains a list of special requirements/barriers faced by developing countries and offers examples of strategies to overcome such barriers.

Barriers to Access and Public Policies to overcome Barriers

	Barrier/obstacle	Examples of strategies to overcome the barriers
1	Low levels of purchasing power in certain rural and sub-urban areas	• Subsidies to the benefit of end-users, to ensure broadband adoption, once access is secured • Discounted offers from operators to end-users • Telecentres for shared use to kick- start broadband markets • Public-private partnerships (PPPs)
2	Limited financial resources available via some USFs	• Policy-makers should work with operators, depending on local needs and government funding, to ensure USF is properly sourced and effective • Support (e.g. from international agencies) for ad-hoc projects • Priority given to UAS projects based on strict and clear criteria
3	The low levels of ICT skills of some of the population	• ICT training • Connecting up educational establishments • ICT lessons in schools and universities, and • ICT equipment furnished at low or no cost
4	The lack of basic commodities (water, electricity, etc.)	• Telecentres open to the public where access to commodities is guaranteed • Wi-Fi access in public spaces where access to commodities is guaranteed
5	The limited availability of consumer electronic equipment	• Distribution of equipment directly, or subsidies for consumer electronic equipment by poor households • Review import duty regimes to ensure they are effective • Equipment approval (supply) policies should not be too onerous or restrictive
6	High tax rates on telecom services or equipment	• Targeted tax and import duty reductions on broadband services and devices, including removal of luxury taxes
7	Lack of infrastructure/ high costs of deployment	• National broadband plan, including roll-out of a mutualized national backbone, as well as in-building infrastructure • Grants to operators to build out infrastructure • Sharing of infrastructure and works
8	Administrative delays in authorizations to deploy new infrastructure	• Involve relevant agencies and Ministries early • Streamline licensing procedures • Eliminate red-tape and delays • Remove barriers and obstacles to owning land
9	Limited economic growth in certain areas	• Ongoing subsidy programs on the demand side, following investment on the supply side
10	Limitations in amount of spectrum available	• Streamline spectrum licensing and re-farming practices • Implementation of the digital switch-over • More effective policies for spectrum allocation/assignment
11	Limited availability of relevant local content	• Subsidies and awards for the development of local content • Development of e-government services, open government/freedom of information policies

In addition, ITU-D Report "Access technology for broadband telecommunications including IMT, for developing countries"[41] provides developing countries with an understanding of the different technologies available for broadband access in urban, rural and remote areas using both wired and wireless technologies for terrestrial and satellite telecommunications, including IMT. The Report covers technical issues involved in deploying broadband access technologies by identifying the factors influencing the effective deployment of such technologies, as well as their applications, with a focus on technologies and standards that are recognized or under study within ITU-R and ITU-T.

3   IMT system characteristics, technologies and standards

3.1   Introduction

International Mobile Telecommunications (IMT) encompasses IMT-2000, IMT-Advanced and IMT-2020 collectively based on Resolution ITU-R 56.
The capabilities of IMT systems are being continuously enhanced in line with user trends and technology developments.

Recommendation ITU-R M.1457 contain the detailed specifications of the terrestrial radio interface of IMT-2000. Recommendations ITU-R M.2012 and ITU-R M.2150 contains, respectively, the detailed specifications of the terrestrial radio interfaces of IMT-2000 and IMT-Advanced.

3.2   IMT system concepts and objectives

IMT system concepts

IMT-2000, third generation mobile systems started service around the year 2000, and IMT systems provide access by means of one or more radio links to a wide range of telecommunication services including advanced mobile services, supported by fixed networks (e.g. PSTN/Internet), which are increasingly packet-based, and other services specific to mobile users.

It is described in the Recommendation ITU-R M.1645 that the framework of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network is based on the global user and technology trends, including the needs of developing countries. International Mobile Telecommunications – Advanced (IMT-Advanced) is a mobile system that includes the new capabilities of IMT that go beyond those of IMT-2000.

The term "IMT-Advanced" is applied to those systems, system components, and related aspects that include new radio interface(s) that support the new capabilities of systems beyond IMT-2000[42]. IMT-Advanced systems provide enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility were established as targets for research)[43].

IMT-Advanced systems have capabilities for high-quality multimedia applications within wide range of services and platforms, providing a significant improvement in performance and quality of current services, and support low to high mobility applications and a wide range of data rates in accordance with user and service demands in multiple user environments.

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[41] ITU-D Report "Access technology for broadband telecommunications including IMT, for developing countries", available at http://www.itu.int/pub/D-STG-SG02.25-2014.

[42] As described in Recommendation ITU-R M.1645, systems beyond IMT-2000 will encompass the capabilities of previous systems, and the enhancement and future developments of IMT-2000 that fulfil the criteria in *resolves* 2 of Resolution ITU-R 56 may also be part of IMT-Advanced.

[43] Data rates sourced from Recommendation ITU-R M.1645.

The capabilities of IMT-Advanced systems are being continuously enhanced in line with technology developments.

The global operation and economy of scale are key requirements for the success of mobile telecommunication systems. It is desirable to agree on a harmonized time-frame for developing common technical, operational and spectrum-related parameters of systems, taking account of relevant IMT-2000 and other experience.

Maximizing the commonality between IMT-Advanced air interfaces may lead to reduced complexity and a lower incremental cost of multi-mode terminals.

3.2.1 Capabilities of IMT-2020

IMT-2020 systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-Advanced. IMT-2020 systems support low to high mobility applications and a wide range of data rates in accordance with user and service demands in multiple user environments. IMT-2020 also has capabilities for high quality multimedia applications within a wide range of services and platforms, providing a significant improvement in performance and quality of service.

A broad variety of capabilities, tightly coupled with intended usage scenarios and applications for IMT-2020 is envisioned. Different usage scenarios along with the current and future trends will result in a great diversity/variety of requirements. The key design principles are flexibility and diversity to serve many different use cases and scenarios, for which the capabilities of IMT-2020, described in the following paragraphs, will have different relevance and applicability. In addition, the constraints on network energy consumption and the spectrum resource will need to be considered.

IMT-2020 should be able to provide these capabilities without undue burden on energy consumption, network equipment cost and deployment cost to make future IMT sustainable and affordable.

The key capabilities of IMT-2020 are shown in Fig. 3, compared with those of IMT-Advanced.

FIGURE 3

Enhancement of key capabilities from IMT-Advanced to IMT-2020
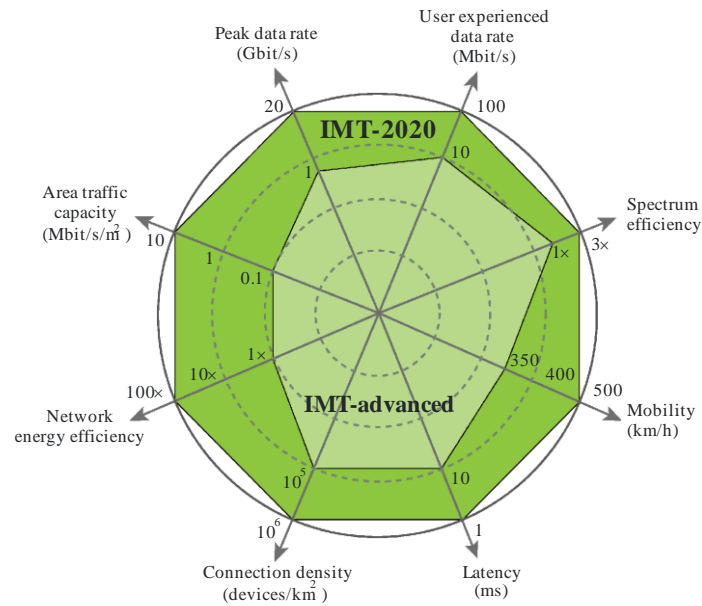
M.2083-03

Objectives

Objectives of IMT-2000 are defined in Recommendation ITU-R M.687 – IMT-2000, and were finally revised in 1997, including general objectives, technical objectives, and operational objectives. For more details please refer to the original Recommendation.

Objectives and vision for IMT for 2020 and beyond are established in Recommendation ITU-R M.2083, by describing potential user and application trends, growth in traffic, technological trends and spectrum implications, and by providing guidelines on the framework and the capabilities for IMT for 2020 and beyond.

Objectives of the future development of IMT-2000 and systems beyond IMT-2000 are also summarized in Recommendation ITU-R M.1645 from the view point of multiple perspectives as in the next table taken from section 4.2.2 of Recommendation ITU-R M.1645 as follows:

Objectives from multiple perspectives

Perspective	Objectives
END USER	Ubiquitous mobile access Easy access to applications and services Appropriate quality at reasonable cost Easily understandable user interface Long equipment and battery life Large choice of terminals Enhanced service capabilities User-friendly billing capabilities

Perspective	Objectives
CONTENT PROVIDER	Flexible billing capabilities Ability to adapt content to user requirements depending on terminal, location and user preferences Access to a very large marketplace through a high similarity of application programming interfaces
SERVICE PROVIDER	Fast, open service creation, validation and provisioning Quality of service (QoS) and security management Automatic service adaptation as a function of available data rate and type of terminal Flexible billing capabilities
NETWORK OPERATOR	Optimization of resources (spectrum and equipment) QoS and security management Ability to provide differentiated services Flexible network configuration Reduced cost of terminals and network equipment based on global economies of scale Smooth transition from IMT-2000 to systems beyond IMT-2000 Maximization of sharing capabilities between IMT-2000 and systems beyond IMT-2000 Single authentication (independent of the access network) Flexible billing capabilities Access type selection optimizing service delivery
MANUFACTURER/ APPLICATION DEVELOPER	Reduced cost of terminals and network equipment based on global economies of scale Access to a global marketplace Open physical and logical interfaces between modular and integrated subsystems Programmable platforms that enable fast and low-cost development

3.3   IMT architecture and standards

Recommendation ITU-R M.1645 defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network based on the global user and technology trends, and the needs of developing countries.
Since the year of 2000, the technical specifications of IMT-2000 have been continually enhanced. IMT-2000,IMT-Advanced and IMT-2020 are defined by a set of interdependent ITU Recommendations which are referred to in this Handbook.

There are a number of other ITU-R Recommendations for IMT (Recommendations ITU-R M.1036, ITU-R M.1580, ITU-R M.1581, ITU-R M.1579, etc.) that provide relevant implementation aspects enabling the most effective and efficient use and deployment of systems – while minimizing the impact on other systems or services in these and in adjacent bands – and facilitating the growth of IMT systems[44].

For more information on ITU-R Recommendations and Reports please refer to Annex B.

3.3.1   IMT Radio Access Network and standards

Recommendation ITU-R M.1457 provides the detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000). Recommendation ITU-R M.2012 and ITU-R M.2150 provides, respectively, the detailed specifications of the terrestrial

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[44] Recommendations ITU-R M.1457,ITU-R M.2012 and ITU-R M.2150 are separate, independent, and self-contained Recommendations, each one with a specific Scope. ThisRecommendations will evolve independently, and there could be some overlap reflected by commonality in content between the documents.

radio interfaces of International Mobile Telecommunications-Advanced (IMT-Advanced) and International Mobile Telecommunications-2020 (IMT-2020). These Recommendations provide specific information regarding the air interfaces that are used in the terrestrial IMT networks.

Recommendation ITU-R M.1457 contains overviews and detailed specifications of each of the IMT-2000 radio interfaces:

–   (Section 5.1) IMT-2000 CDMA Direct Spread

–   (Section 5.2) IMT-2000 CDMA Multi-Carrier

–   (Section 5.3) IMT-2000 CDMA TDD

–   (Section 5.4) IMT-2000 TDMA Single-Carrier

–   (Section 5.5) IMT-2000 FDMA/TDMA

–   (Section 5.6) IMT-2000 OFDMA TDD WMAN.

Recommendation ITU-R M.2012 contains detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced. The Recommendation includes both overviews and detailed specifications of the two IMT-Advanced radio interfaces:

–   (Annex 1) Specification of the LTE-Advanced radio interface technology.

–   (Annex 2) Specification of the WirelessMAN-Advanced radio interface technology.

Recommendation ITU-R M.2150 contains detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced. The Recommendation includes both overviews and detailed specifications of the three IMT-2020 radio interfaces:

–   (Annex 1) Specification of the 3GGP 5G-SRIT radio interface technology.

–   (Annex 2) Specification of the 3GGP 5G-RIT radio interface technology.

–   (Annex 2) Specification of the TSDSI 5Gi radio interface technology.

3.3.1.1   IMT-2000

3.3.1.1.1   IMT-2000 CDMA Direct Spread

This section includes CDMA Direct Spread and E-UTRAN.

CDMA Direct Spread

The IMT-2000 radio-interface specifications for CDMA Direct Spread technology are developed by a partnership of SDOs[45]. This radio interface is called Universal Terrestrial Radio Access (UTRA) FDD or Wideband CDMA (WCDMA).

The overall architecture of the radio access network is shown in Figure 4. The architecture of this radio interface consists of a set of radio network subsystems (RNS) connected to the core network (CN) through the Iu interface. An RNS consists of a radio network controller (RNC) and one or more entities called Node B. Node B is connected to the RNC through the Iub interface. Each NodeB can handle one or more cells. The RNC is responsible for the handover decisions that

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[45] Currently, these specifications are developed within the third generation partnership project (3GPP) where the participating SDOs are the Association of Radio Industries and Businesses (ARIB), China Communications Standards Association (CCSA), the European Telecommunications Standards Institute (ETSI), Alliance for Telecommunications Industry Solutions (ATIS Committee T1P1), Telecommunications Technology Association (TTA) and Telecommunication Technology Committee (TTC).

require signalling to the user equipment (UE). In case macro diversity between different Node Bs is to be supported, the RNC comprises a combining/splitting function to support this. Node B can comprise an optional combining/splitting function to support macro diversity within a Node B. The RNCs of the RNS can be interconnected through the Iur interface. Iu and Iur are logical interfaces, i.e. the Iur interface can be conveyed over a direct physical connection between RNCs or via any suitable transport network.

FIGURE 4

**Radio access network architecture
(Cells are indicated by ellipses)**
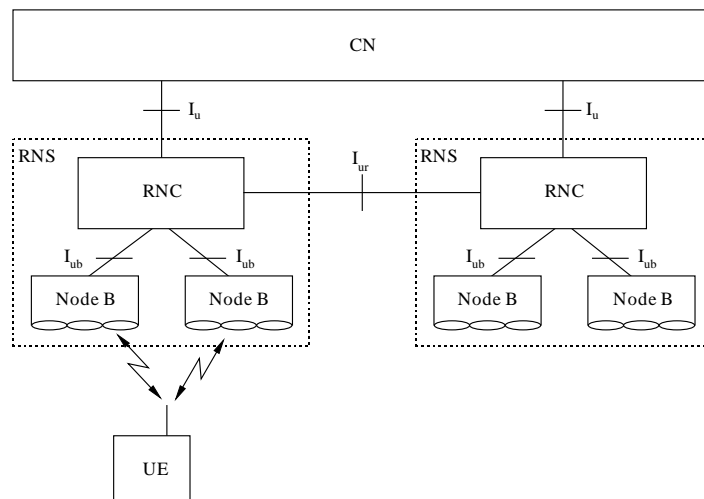
Global Trends04

E-UTRAN (Evolved Universal Terrestrial Radio Access Network = LTE)

E-UTRAN has been introduced for the evolution of the radio-access technology towards a high-data-rate, low-latency and packet-optimized radio-access technology.

E-UTRAN supports scalable bandwidth operation below 5 MHz bandwidth options up to 20 MHz in both the uplink and downlink. Harmonization of paired and unpaired operation is highly considered to avoid unnecessary fragmentation of technologies.

The radio access network architecture of E-UTRAN consists of the evolved UTRAN Node Bs (eNBs). eNBs host the functions for radio resource management, IP header compression and encryption of user data stream, etc. eNBs are interconnected with each other and connected to an Evolved Packet Core (EPC).

The E-UTRAN radio access network consists of eNBs, providing the user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), and more specifically to the MME (Mobility Management Entity) by means of the S1-C and to the S-GW (Serving Gateway) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs/Serving Gateways and eNBs.

The E-UTRAN radio access network architecture is illustrated in Figure 5.

FIGURE 5

Overall architecture
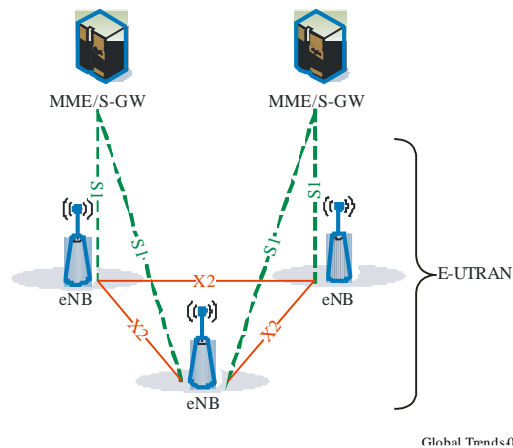
The eNB hosts the following functions:

– functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

– IP header compression and encryption of user data stream;

– selection of an MME at UE attachment;

– routing of User Plane data towards S-GW;

– scheduling and transmission of paging messages (originated from the MME);

– scheduling and transmission of broadcast information (originated from the MME or O&M);

– measurement and measurement reporting configuration for mobility and scheduling.

The MME hosts the following functions:

– NAS signalling;

– NAS signalling security;

– Inter CN node signalling for mobility between 3GPP access networks;

– Idle mode UE Reachability (including control and execution of paging retransmission);

– Tracking Area list management (for UE in idle and active mode);

– PDN GW and Serving GW selection;

– MME selection for handovers with MME change;

– SGSN selection for handovers to GSM or IMT-2000 3GPP access networks;

– Roaming;

– Authentication;

– Bearer management functions including dedicated bearer establishment.

3.3.1.1.2 IMT-2000 CDMA Multi-Carrier

The IMT-2000 radio interface specifications for CDMA multi-carrier (MC) technology are developed by a partnership of SDOs (3GPP2)[46]. This radio interface is called cdma2000.

cdma2000 1xRTT and High Rate Packet Data (HRPD) Access Network Architecture

Figures 6 and 7 below show the relationship among network components in support of Mobile Station (MS) originations, MS terminations, and direct Base Station (BS) to Base Station (BS) soft/softer handoff operations. These two Figures also depict a logical architecture that does not imply any particular physical implementation. The InterWorking Function (IWF) for circuit-oriented data calls is assumed to be located at the circuit-switched Mobile Switching Center (MSC), and the SDU (Selection/Distribution Unit) function is considered to be co-located with the source BSC (Base Station Controller).

FIGURE 6

Reference Model for Circuit-Switched cdma2000 Access Network Interfaces

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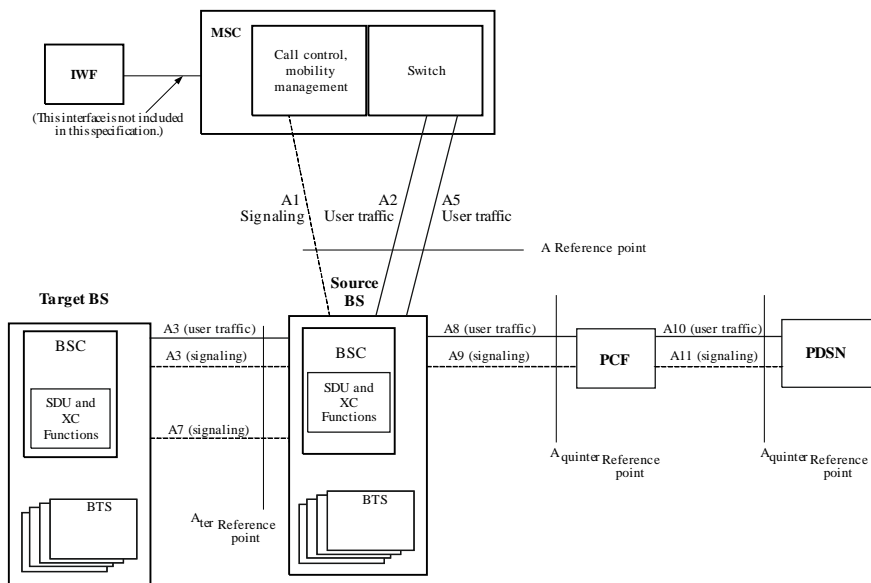
[46] Currently, these specifications are developed within the Third Generation Partnership Project 2 (3GPP2), where the participating SDOs are ARIB, CCSA, TIA, TTA and TTC.

FIGURE 7

Reference Model for Packet-based cdma2000 Access Network Interfaces
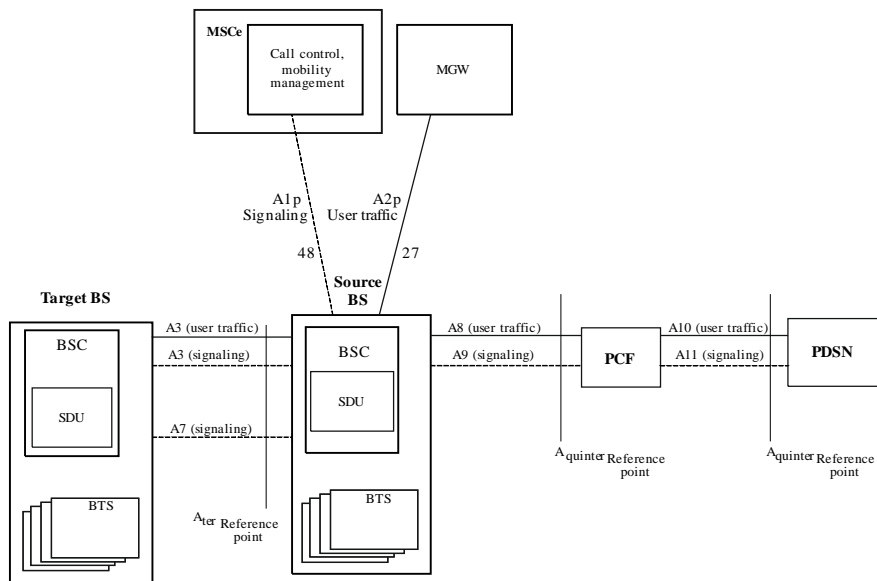
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The interfaces defined in Figures 6 and 7 provide:

– bearer (user traffic) connections (A2, A2p, A3 (traffic), A5, A8, and A10);

– a signalling connection between the channel element component of the target BS and the SDU function in the source BS (A3 signalling);

– a direct BS to BS signalling connection (A7);

– a signalling connection between the BS and the circuit-switched MSC (A1);

– a signalling connection between the BS and the MSCe (A1p);

– a signalling connection between the BS and PCF (A9); and

– a signalling connection between a PCF and PDSN pair (A11). A11 signalling messages are also used for passing accounting related and other information from the PCF to the PDSN.

In general, the functions specified on the interfaces are based on the premise that the interfaces carry signalling information that traverses the following logical paths:

– between the BS and MSC only (e.g. BS management information);

– between the MS and the MSC via the BS (e.g. the BS maps air interface messages to the A1 or A1p interface);

– between the BS and other network elements via the MSC;

– between the source BS and the target BS;

– between the BS and the PCF;

– between the PCF and the PDSN; and

– between the MS and the PDSN (e.g. authorization information and Mobile Internet Protocol (MIP) signalling).

cdma2000 Evolved High Rate Packet Data (eHRPD) Access Network Architecture

The eHRPD IOS (Interoperability Specification) messaging and call flows are based on the Architecture Reference Model shown in Figure 8[47] and in Figure 9[48]. In the Figures, solid lines indicate signalling and bearer and dashed lines indicate only signalling.

The eHRPD call flows include the E-UTRAN and other 3GPP access entities (S-GW, P-GW, HSS and PCRF). Refer to TS 23.402 [1] for the architecture model and descriptions of these network entities and associated interfaces.

FIGURE 8

Session Control and Mobility Management in the evolved Access Network
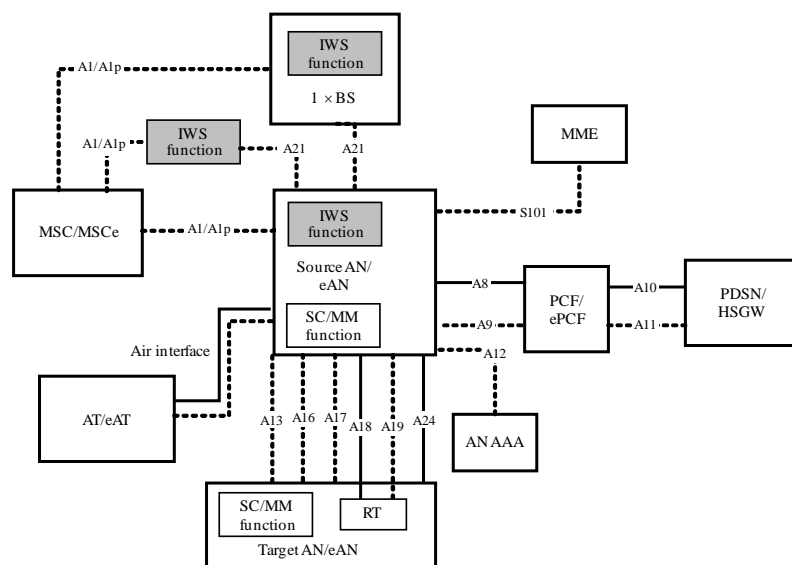
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[47] The Interworking Solution (IWS) Function in Figure 8 may be collocated at either the 1x Base Station (BS) or at the HRPD eAN, or may be a standalone entity. When the IWS function is collocated at the 1x BS, the A21 interface is supported between the 1x BS and the HRPD eAN, and the A1/A1p interface is supported between the Mobile Switching Center (MSC) and the 1x BS. When the IWS function is part of the HRPD eAN, the A1/A1p interface between the MSC and the HRPD eAN exists, and the A21 interface is internal to the HRPD eAN. When the IWS is a standalone entity, the A1/A1p interface is supported between the MSC and the IWS, and the A21 interface is supported between the IWS and the HRPD eAN. PDSN and HSGW functions may not be in the same physical entity.

[48] The IWS Function in Figure 9 may be collocated at either the 1x BS or at the HRPD ePCF, or may be a standalone entity. When the IWS function is collocated at the 1x BS, the A21 interface is supported between the 1x BS and the HRPD ePCF, and the A1/A1p interface is supported between the MSC and the 1x BS. When the IWS function is part of the HRPD ePCF, the A1/A1p interface between the MSC and the HRPD ePCF exists, and the A21 interface is internal to the HRPD ePCF. When the IWS is a standalone entity, the A1/A1p interface is supported between the MSC and the IWS, and the A21 interface is supported between the IWS and the HRPD ePCF. PDSN and HSGW functions may not be in the same physical entity.

FIGURE 9

Session Control and Mobility Management in the evolved Packet Control Function

Global Trends09

3.3.1.1.3 IMT-2000 CDMA TDD

The IMT-2000 radio interface specifications for CDMA TDD technology are developed by a partnership of standards development organizations (SDOs)[49]. This radio interface is called the Universal Terrestrial Radio Access (UTRA) time division duplex (TDD), where three options, called 1.28 Mchip/s TDD (TD-SCDMA)[50], 3.84 Mchip/s TDD and 7.68 Mchip/s TDD can be distinguished. E-UTRAN TDD has been introduced for the evolution of UTRAN TDD towards high data rate, low latency and packet optimized radio access technology.

For the IMT-2000 CDMA TDD RAN overall architecture please refer to Figure 4 above. For the E-UTRA TDD RAN overall architecture please refer to Figure 5.

3.3.1.1.4 IMT-2000 TDMA Single-Carrier

The IMT-2000 TDMA single-carrier radio interface specifications contain two variations depending on whether a TIA/EIA-41 circuit switched network component or a GSM evolved UMTS circuit switched network component is used. In either case, a common enhanced GSM General Packet Radio Service (GPRS) packet switched network component is used.

Radio interface use with TIA/EIA-41 circuit switched network

The IMT-2000 radio interface specifications for TDMA single-carrier technology utilizing the TIA/EIA-41 circuit switched network component are developed by TIA TR45.3 with input from the Universal Wireless Communications Consortium. This radio interface is called Universal Wireless Communication-136 (UWC-136), which is specified by American National Standard TIA/EIA-136.

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[49] Currently, these specifications are developed within the third generation partnership project (3GPP) where the participating SDOs are ARIB, ATIS, CCSA, ETSI, TTA and TTC.

[50] The same name TD-SCDMA was previously used for one of the original proposals that was further refined following the harmonization process.

It has been developed with the objective of maximum commonality between TIA/EIA-136 and GSM EDGE GPRS.

This radio interface was designed to provide a TIA/EIA-136 (designated as 136)-based radio transmission technology that meets ITU-R's requirements for IMT-2000. It maintains the TDMA community's philosophy of evolution from 1st to 3rd Generation systems while addressing the specific desires and goals of the TDMA community for a 3rd Generation system.

Radio interface used with GSM evolved UMTS circuit switched network component

This radio interface provides an evolution path for an additional pre-IMT-2000 technology (GSM/GPRS) to IMT-2000 TDMA Single-Carrier. The IMT-2000 radio interface specifications for TDMA Single-Carrier technology utilizing the GSM evolved UMTS circuit switched network component are developed by 3GPP and transposed by ATIS Wireless Technologies and Systems Committee (WTSC). The circuit switched component uses a common 200 kHz carrier as does the GSM EDGE enhanced GPRS phase 2 packet switched component, as used by 136EHS, to provide high speed data (384 kbps). In addition a new dual carrier configuration is supported

TIA/EIA-41 Circuit Switched Network component

Figure 10 presents the network elements and the associated reference points that comprise a system utilizing the TIA/EIA-41 circuit switched network component. The primary TIA/EIA-41 network node visible to the serving GPRS support node (SGSN) is the gateway mobile switching centre (MSC)/visitor location register (VLR). The interface between the TIA/EIA-41 gateway MSC/VLR and the SGSN is the Gs' interface, which allows the tunnelling of TIA/EIA-136 signalling messages between the MS and the gateway MSC/VLR. The tunnelling of these signalling messages is performed transparently through the SGSN. Between the MS and the SGSN, the signalling messages are transported using the tunnelling of messages (TOM) protocol layer. TOM uses the LLC unacknowledged mode procedures to transport the signalling messages. Between the SGSN and the gateway MSC/VLR, the messages are transported using the BSSAP+ protocol.

Upon receiving a TIA/EIA-136 signalling message from a MS via the TOM protocol, the SGSN forwards the message to the appropriate gateway MSC/VLR using the BSSAP+ protocol. Upon receiving a TIA/EIA-136 signalling message from a gateway MSC/VLR via the BSSAP+ protocol, the SGSN forwards the message to the indicated MS using the TOM protocol.

MS supporting both the TIA/EIA-41 circuit-switched network component and packet services (Class B136 MS) perform location updates with the circuit system by tunnelling the registration message to the gateway MSC/VLR. When an incoming call arrives for a given MS, the gateway MSC/VLR associated with the latest registration pages the MS through the SGSN. The page can be a hard page (no Layer 3 information included in the message), in which case, the Gs' interface paging procedures are used by the MSC/VLR and the SGSN. If the circuit page is not for a voice call or, if additional parameters are associated with the page, a Layer 3 page message is tunnelled to the MS by the MSC/VLR. Upon receiving a page, the MS pauses the packet data session and leaves the packet data channel for a suitable DCCH. Broadcast information is provided on the packet control channel to assist the MS with a list of candidate DCCHs. Once on a DCCH, the MS sends a page response. The remaining call setup procedures, such as traffic channel designation, proceed as in a normal page response situation.

FIGURE 10

TIA/EIA-41 Circuit Switched Network components

Global Trends-10
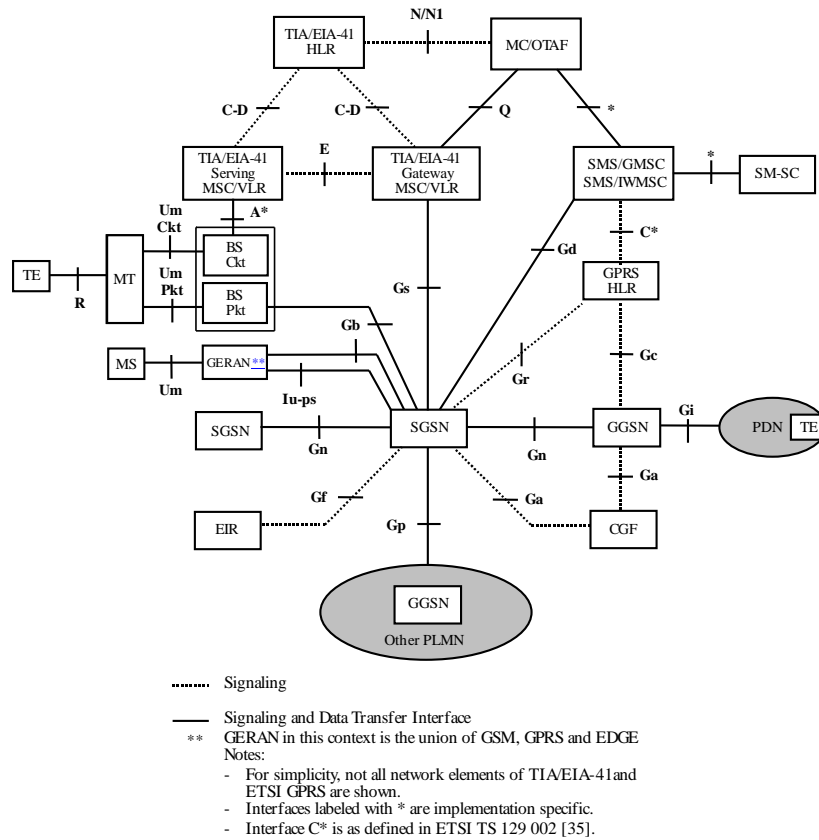
GSM evolved UMTS Circuit Switched Network component

Figure 11 presents the network elements and the associated reference points that comprise a system utilizing the GSM evolved UMTS circuit switched network component along with the common GSM EDGE enhanced GPRS or EGPRS2 packet switched component.

Since the TDMA-SC network supports a common EDGE 136EHS bearer connected to a core enhanced GPRS backbone network or a GSM EDGE radio access network, along with either circuit switched component, GSM EDGE Release 5, Release 6, Release 7 and Release 8 mobile stations and functions are supported. In addition to the Gs interface, GSM SMS functionality is also supported through the Gd interface[51].

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[51] For simplicity, not all network elements of this system are shown in Figure 11.

FIGURE 11

GSM evolved UMTS Circuit Switched Network component

Global Trends-11

3.3.1.1.5 IMT-2000 FDMA/TDMA

The IMT-2000 radio interface specifications for FDMA/TDMA technology are defined by a set of ETSI standards. This radio interface is called digital enhanced cordless telecommunications (DECT). This technology provides a comprehensive set of protocols which provide the flexibility to interwork between numerous different applications and networks. Thus a local and/or public network is not part of this specification. Figure 12 illustrates this.

The radio interface covers, in principle, only the air interface between the fixed part (FP) and portable part (PP). The interworking unit (IWU) between a network and the fixed radio termination (FT) is network specific and is not part of the common interface (CI) specification, but the profile specifications define IWUs for various networks. Similarly, the end system (ES)[52], the application(s) in a PP is also excluded. The CI specification contains general end-to-end

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[52] An ES depends on the application supported in a PP. For a speech telephony application the ES may be a microphone, speaker, keyboard and display. The ES could equally well be a serial computer port, a fax machine or whatever the application requires.

compatibility requirements e.g. on speech transmission. The IWU and ES are also subject to general attachment requirements for the relevant public network, e.g. the PSTN/ISDN.

FIGURE 12

The Common Interface structure
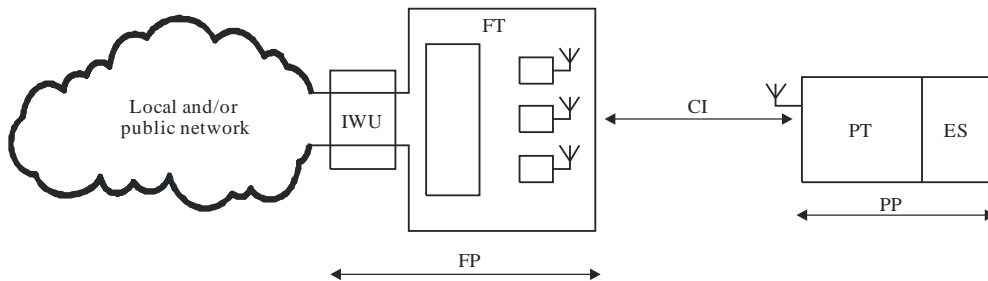
Global Trends-12

For each specific network, local or global, the specific services and features of that network are made available via the air interface to the users of PPs/handsets. Except for cordless capability and mobility, this standard does not offer a specific service; it is transparent to the services provided by the connected network. Thus the CI standard is, and has to be, a tool box with protocols and messages from which a selection is made to access any specific network, and to provide means for market success for simple residential systems as well as for much more complex systems, e.g. office ISDN services.

IMT-2000 FDMA/TDMA is very suitable to be used as radio access system to connect to mobile networks. Specifically the access to GSM/UMTS networks has been specified in detail, which allows the provision of GSM/UMTS services via DECT. The multipart TS 101 863 contains the UMTS interworking specification.

3.3.1.1.6 IMT-2000 OFDMA TDD WMAN

The IEEE standard relevant for IMT-2000 OFDMA TDD WMAN, designated as IEEE Std 802.16, is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. It is published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE).

The radio interface technology specified in IEEE Standard 802.16 is flexible, for use in a wide variety of applications, operating frequencies, and regulatory environments. IEEE 802.16 includes multiple physical layer specifications, one of which is known as WirelessMAN-OFDMA. OFDMA TDD WMAN is a special case of WirelessMAN-OFDMA specifying a particular interoperable radio interface. The component of OFDMA TDD WMAN defined here operates in TDD mode. The OFDMA TDD WMAN radio interface is designed to carry packet-based traffic, including IP. It is flexible enough to support a variety of higher-layer network architectures for fixed, nomadic, or fully mobile use, with handover support. It can readily support functionality suitable for generic data as well as time-critical voice and multimedia services, broadcast and multicast services, and mandated regulatory services.

The radio interface standard specifies Layers 1 and 2; the specification of the higher network layers is not included. It offers the advantage of flexibility and openness at the interface between Layers 2 and 3 and it supports a variety of network infrastructures. The radio interface is compatible with the network architectures defined in Recommendation ITU-T Q.1701. In particular, a network

architecture design to make optimum use of IEEE Standard 802.16 and the OFDMA TDD WMAN radio interface is described in the "WiMAX End to End Network Systems Architecture Stage 2-3", available from the WiMAX Forum[53].

The protocol layering is illustrated in Figure 13. The MAC comprises three sub-layers. The service-specific convergence sub-layer (CS) provides any transformation or mapping of external network data, received through the CS service access point (SAP), into MAC service data units (SDUs) received by the MAC common part sub-layer (CPS) through the MAC SAP. This includes classifying external network SDUs and associating them to the proper MAC service flow identifier (SFID) and connection identifier (CID). It may also include such functions as payload header suppression (PHS). Multiple CS specifications are provided for interfacing with various protocols. The internal format of the CS payload is unique to the CS, and the MAC CPS is not required to understand the format of or parse any information from the CS payload.

FIGURE 13

OFDMA TDD WMAN protocol layering, showing service access points (SAPs)
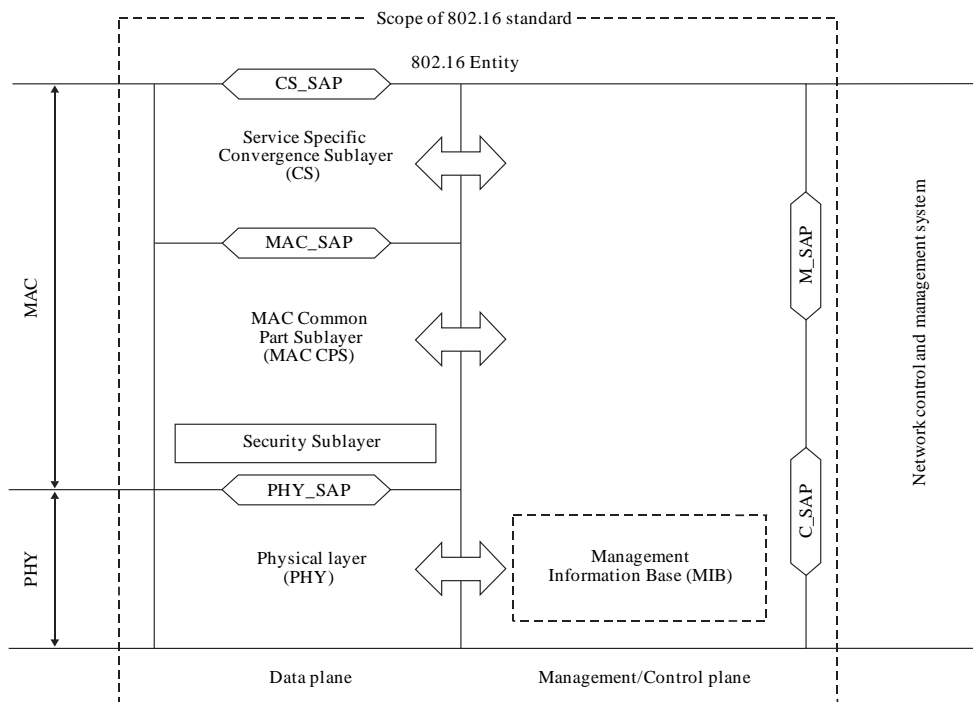
Global Trends-13

The MAC CPS provides the core MAC functionality of system access, bandwidth allocation, connection establishment, and connection maintenance. It receives data from the various CSs, through the MAC SAP, classified to particular MAC connections.

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[53] WiMAX End to End Network Systems Architecture Stage 2-3, available at http://www.wimaxforum.org/technology/documents/.

3.3.1.2   IMT-Advanced

3.3.1.2.1   LTE-Advanced

The LTE-Advanced radio-access network has a flat architecture with a single type of node, the eNodeB, which is responsible for all radio-related functions in one or several cells. The eNodeB is connected to the core network by means of the S1 interface, more specifically to the *serving gateway* (S-GW) by means of the user-plane part, S1-u, and to the Mobility Management Entity (MME) by means of the control-plane part, S1-c. One eNodeB can interface to multiple MMEs/S-GWs for the purpose of load sharing and redundancy.

The X2 interface, connecting eNodeBs to each other, is mainly used to support active-mode mobility. This interface may also be used for multi-cell Radio Resource Management (RRM) functions such as Inter-Cell Interference Coordination (ICIC). The X2 interface is also used to support lossless mobility between neighbouring cells by means of packet forwarding.

Inter-cell interference coordination (ICIC), where neighbour cells exchange information aiding the scheduling in order to reduce interference, is supported for the RITs. ICIC can be used for homogenous deployments with non-overlapping cells of similar transmission power, as well as for heterogeneous deployments where a higher-power cell overlays one or several lower-power nodes. The LTE-Advanced Radio-access network interfaces are illustrated in Figure 14.

FIGURE 14

Radio-access network interfaces
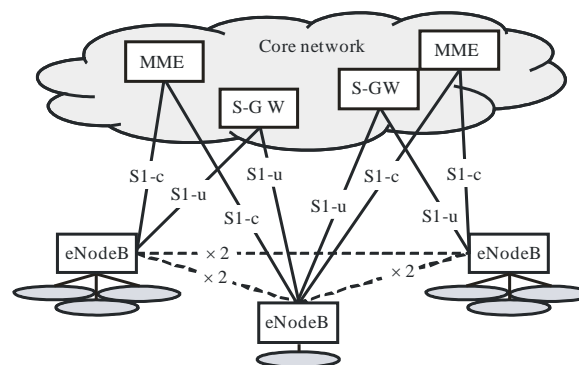
Global Trends-14

3.3.1.2.2   WirelessMAN-Advanced

The IEEE standard relevant for WirelessMAN-Advanced, designated as IEEE Std 802.16.1, is developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access. It is published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE).

Figure 15 illustrates the protocol layering of IEEE Std 802.16.1-2012. The medium access control (MAC) common part sub-layer (CPS) provides the core MAC functionality of system access, bandwidth allocation, connection establishment, and connection maintenance. It receives data from the various convergence sub-layers (CSs), through the MAC service access point (SAP), classified to particular MAC connections. Quality of service (QoS) is applied to the transmission and scheduling of data over the physical layer (PHY). The MAC also contains a separate security sub-layer providing authentication, secure key exchange, and encryption. Data, PHY control, and statistics are transferred between the MAC CPS and the PHY via the PHY SAP. The MAC

comprises three sub-layers. The service-specific CS provides any transformation or mapping of external network data, received through the CS SAP, into MAC service data units (SDUs) received by the MAC CPS through the MAC SAP. This includes classifying external network SDUs and associating them to the proper MAC service flow identifier (SFID) and, for an advanced base station (ABS) or advanced mobile station (AMS), a Station Identifier + Flow Identifier (STID + FID) combination. It may also include such functions as payload header suppression (PHS). Multiple CS specifications are provided for interfacing with various protocols. The internal format of the CS payload is unique to the CS, and the MAC CPS is not required to understand the format of or to parse any information from the CS payload.

FIGURE 15

IEEE 802.16.1 protocol layering, showing service access points (SAPs)
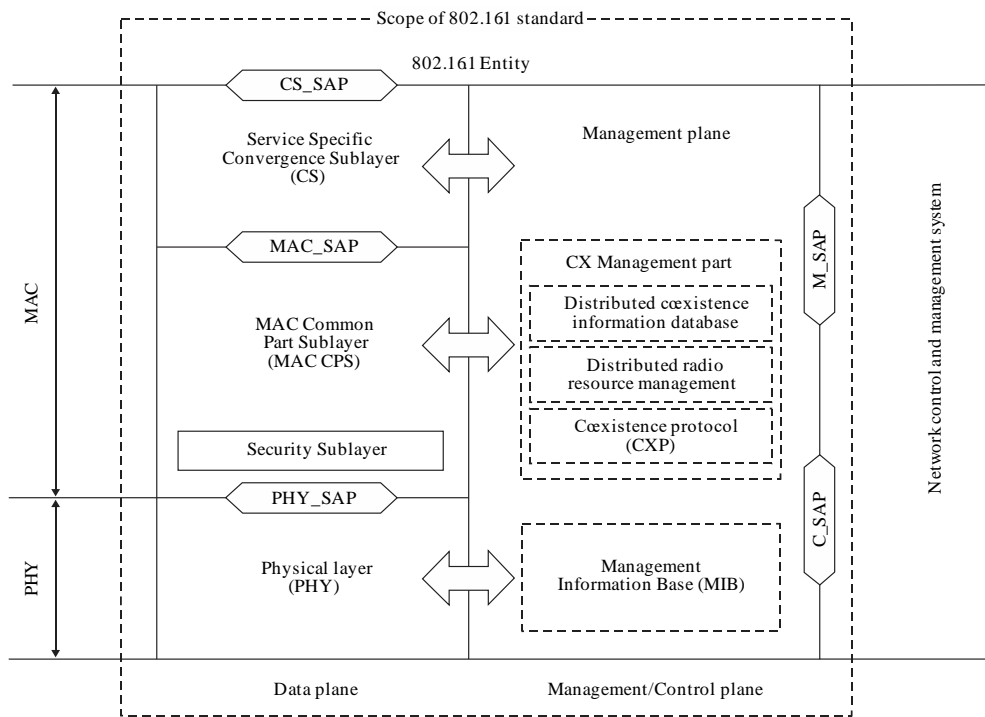
Global Trends-15

3.3.1.3   IMT-2020

3.3.1.3.1   3GPP 5G-SRIT

The IMT-2020 specifications, known as 5G-SRIT, have been developed by 3GPP and consist of long-term evolution (LTE) and new radio (NR) Releases 15 and beyond. In 3GPP terminology, the term Evolved-UMTS Terrestrial Radio Access (E-UTRA) is also used to signify the LTE radio interface.

5G-SRIT is a set of radio interface technologies (RITs) consisting of E-UTRA/LTE as one component RIT and NR as the other component RIT. Both components are designed for operation in IMT spectrum.

The radio-access network of E-UTRA/LTE RIT has a flat architecture with a single type of node, the eNodeB, which is responsible for all radio-related functions in one or several cells. The eNodeB is connected to the core network via the S1 interface, more specifically to the serving gateway (S-

GW) by means of the user-plane part, S1-u, and to the Mobility Management Entity (MME) by means of the control-plane part, S1-c. One eNodeB can connect to multiple MMEs/S-GWs for the purpose of load sharing and redundancy. MMEs/S-GWs can be (re)selected for support of separate dedicated core networks that are designed to meet the requirements of a certain group of devices/customers.

The X2 interface, connecting eNodeBs to each other, is mainly used to support active-mode mobility. This interface may also be used for multi-cell Radio Resource Management (RRM) functions such as ICIC or CoMP. The X2 interface is also used to support lossless mobility between neighbouring cells by means of packet forwarding. The architecture is shown in Fig. 16.

FIGURE 16

Radio-access network interfaces
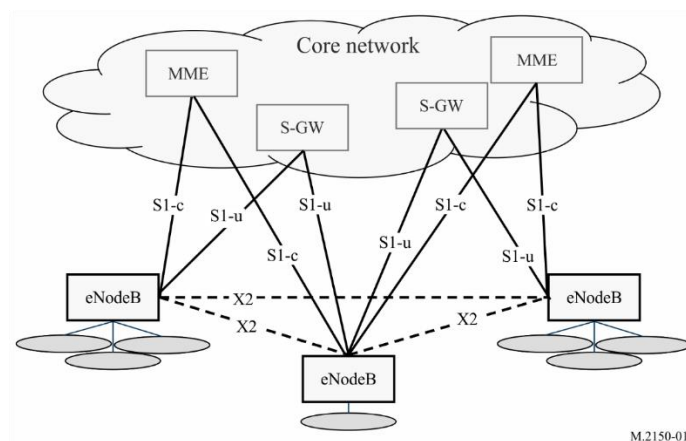
The NR RIT as one component RIT represents the releases 15 and 16 of NR, which uses either 1) FDD operation and therefore is applicable for operation with paired spectrum or 2) TDD operation and therefore is applicable for operation with unpaired spectrum. Channel bandwidths up to 400 MHz and Carrier Aggregation over 16 component carriers are supported, yielding peak data rates up to roughly 140 Gbit/s in the downlink and 65 Gbit/s in the uplink.
An NG-RAN node, is either:

−   A gNB, providing NR user plane and control plane protocol terminations towards the UE; or

−   An ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE.

NG-RAN nodes are interconnected by means of the interface named Xn. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the Access and Mobility Management Function (AMF) by means of the NG-C interface and to the User Plane Function (UPF) by means of the NG-U interface.
The NG-RAN architecture is illustrated in Fig. 17.

FIGURE 17

Overall 5G-SRIT NG-RAN architecture

M.2150-13
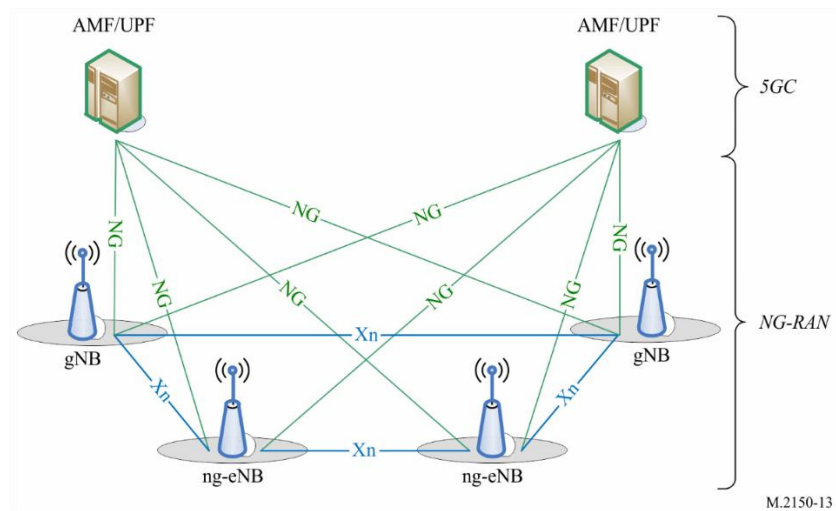
3.3.1.3.2   3GPP 5G-RIT

The IMT-2020 specifications known as 5G RIT have been developed by 3GPP and encompass NR Releases 15 and beyond.

The NG Radio Access Network (NG-RAN) includes NG-RAN nodes that support multiple radio access (e.g. NR, MR-DC of NR and E-UTRA2, etc). The RIT considers the gNB as an NG-RAN node providing NR user plane and control plane protocol terminations towards the UE and connected via the NG interface to the 5GC, and the ng-eNB as NG-RAN node for Multi-Radio Dual Connectivity only.

NG-RAN nodes are interconnected by means of the interface named Xn. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the Access and Mobility Management Function (AMF) by means of the NG-C interface and to the User Plane Function (UPF) by means of the NG-U interface.
The NG-RAN architecture is illustrated in Fig. 18 below.

FIGURE 18

Overall 5G-RIT NG-RAN Architecture
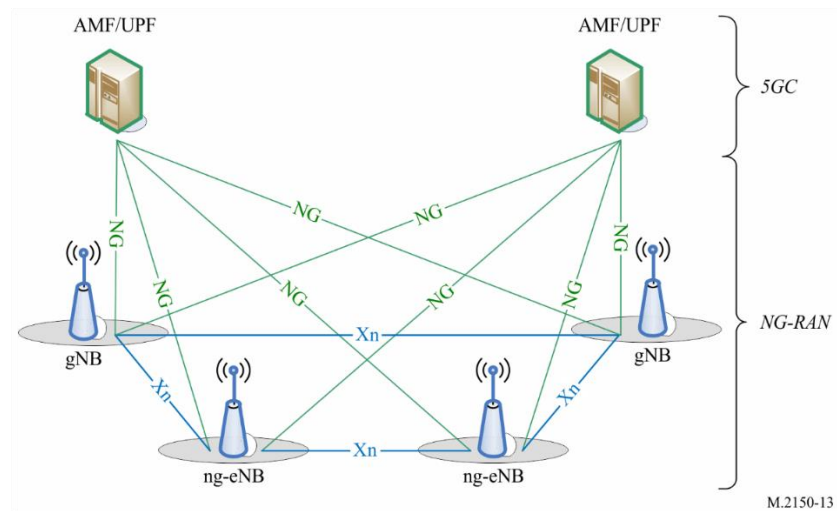
3.3.1.3.3 TSDSI 5Gi

TSDSI RIT (5Gi) is a versatile radio interface that fulfils all the technical performance requirements of IMT-2020 across all the different test environments. This RIT focuses on connecting the next generation of devices and providing services across various sectors. This RIT focuses on:

1   Enhanced spectral efficiency and broadband access.

2   Low latency communication.

3   Support millions of IOT devices.

4   Power efficiency.

5   High speed connectivity.

6   Large Coverage (in particular for Rural areas).

7   Support multiple frequency bands including mmWave spectrum.

While, the current specifications provide a robust RIT, the specification also provides a framework on which future enhancements can be supported, providing a future-proof technology.

The overall RAN protocol architecture is shown in Fig. 19.

FIGURE 19

Control-plane and user-plane protocol stack (AMF is not part of the RAN)

M.2150-42
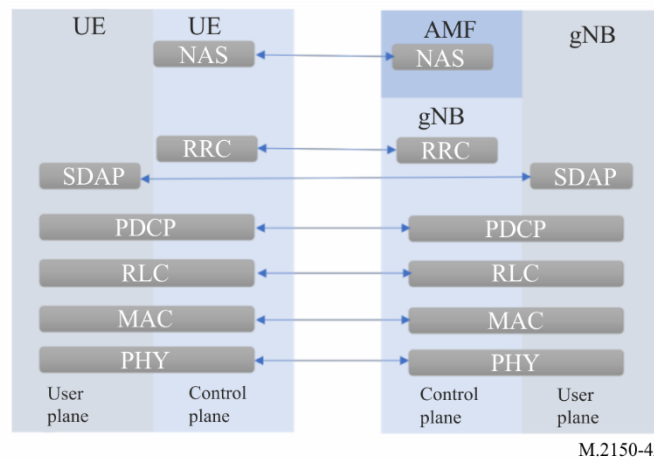
1 Physical layer is responsible for coding (decoding), modulation (demodulation), rate adaptation, multi-antenna processing and appropriate waveform generation.

2 Medium-Access Control (MAC) layer is responsible for scheduling, hybrid-ARQ and multiplexing of logical channels. Physical layer interacts with MAC using transport channels.

3 Radio-link Control (RLC) layer is responsible for packet segmentation and handling retransmissions. MAC layer interfaces with RLC layer using logical channels.

4 Packet Data Convergence Protocol (PDCP) layer provides in-sequence delivery of packets, ciphering functionality and integrity protection. RLC interacts with PDCP using RLC channels

5 Service Data Application Protocol (SDAP) layer is primarily responsible for managing radio bearers and maintaining QoS requirements.

6 Radio Resource Control (RRC) layer is responsible for handling RAN control-plane procedures, transmission of configuration and system parameters.

3.3.2 IMT Core Network and standards

NOTE: ADD TEXT RELATING TO IMT-2020 AND IMT ADVANCED

Q.5021 Protocol for managing capability exposure APIs in IMT-2020 networks

Q.5022 Signalling procedure of energy efficient device-to-device communication for IMT-2020 network

Q.5023 Protocol for managing intelligent network slicing with AI-assisted analysis in IMT-2020 networks

3.3.2.1 Recommendation ITU-T Q.1741.8 – IMT-2000 references to Release 10 of GSM-evolved UMTS core network

This Recommendation identifies the IMT-2000 family member, "GSM evolved UMTS Core Network" corresponding to the "3GPP Release 10".

The core network interfaces identified in this Recommendation ITU-T Q.1741 and the radio interfaces and radio access interfaces which are identified in ITU-R M.1457 constitute a complete system specification for this IMT-2000 family member.

The Recommendation includes 380 items of definition relevant to the network which could be used like a dictionary when readers would like to know compact meaning of any terms.

This Recommendation defines the terms relevant to the core network, of which many are based on definitions given in the references listed in clause 2 of Recommendation ITU-T Q.1741.8.

The core network of 3GPP Release 10 supports IMT-2000 and IMT-Advanced radio access networks as options.

Whereas the basic configuration of a Public Land Mobile Network (PLMN) supporting PS Domain (both GPRS and EPC) and the interconnection to the PSTN/ISDN and PDN is presented in Figure 16. This configuration presents signalling and user traffic interfaces which can be found in a PLMN.

Therefore, all the interfaces within PLMN are external. This Recommendation only describes the internal interfaces in the core network (CN) and the external interfaces to and from CN.

FIGURE 16

**Basic configuration of a 3GPP access PLMN supporting CS and PS services
(using GPRS and EPS) and interfaces**
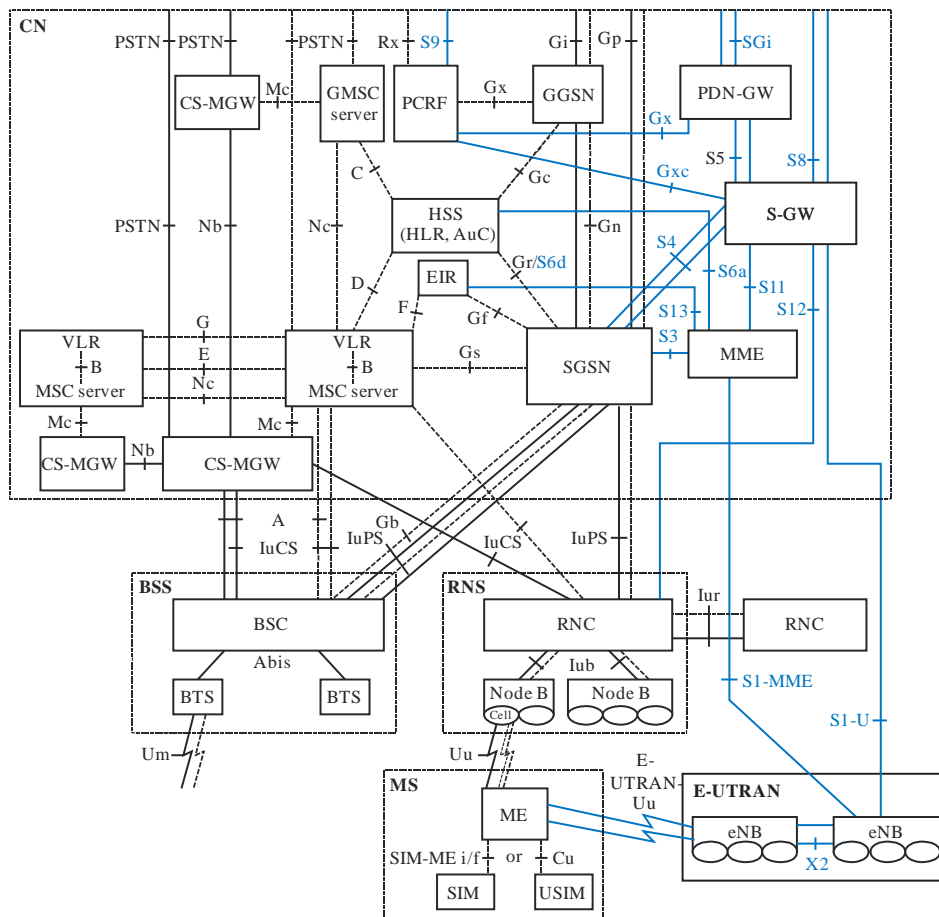
NOTE – The interfaces in blue represent EPS functions and reference points.

3.3.2.2 Recommendation ITU-T Q.1742.11 – IMT 2000 References (3GPP2 up to 31st December 2012) to ANSI-41 evolved Core Network with cdma2000 Access Network

This Recommendation identifies the IMT-2000 Family Member; "ANSI-41 evolved Core Network with cdma2000 Access Network."

The Core Network interfaces identified in this Recommendation and the radio interfaces and radio access network interfaces identified in Recommendation ITU-R M.1457 constitute a complete system specification for this IMT-2000 Family Member.

The Core Network for cdma2000 is based on an evolved ANSI-41 2nd generation mobile system. The core network technical specifications have been developed in a third generation partnership project (approved in 3GPP2 as of 31 December 2006) and transposed to the involved regional Standards Development Organizations (SDOs). The system will support different applications ranging from narrow-band to wide-band communications capability with integrated personal and terminal mobility to meet the user and service requirements.

The Recommendation includes 56 items of definition relevant to the network which could be used like a dictionary when readers would like to know compact meaning of any terms.

The basic architecture for the ANSI-41 evolved Core Network with cdma2000 Access Network family member includes a circuit-based and packet based core network and an all-IP multimedia domain.

Figure 17 presents the network entities and associated reference points that comprise the ANSI-41 evolved Core Network with cdma2000 Access Network. The network entities are represented by squares, triangles and rounded corner rectangles; circles represent the reference points. The network reference model in this Recommendation is the compilation of several reference models currently in use.

FIGURE 17

ANSI-41 evolved Core Network with cdma2000 Access Network Reference Model
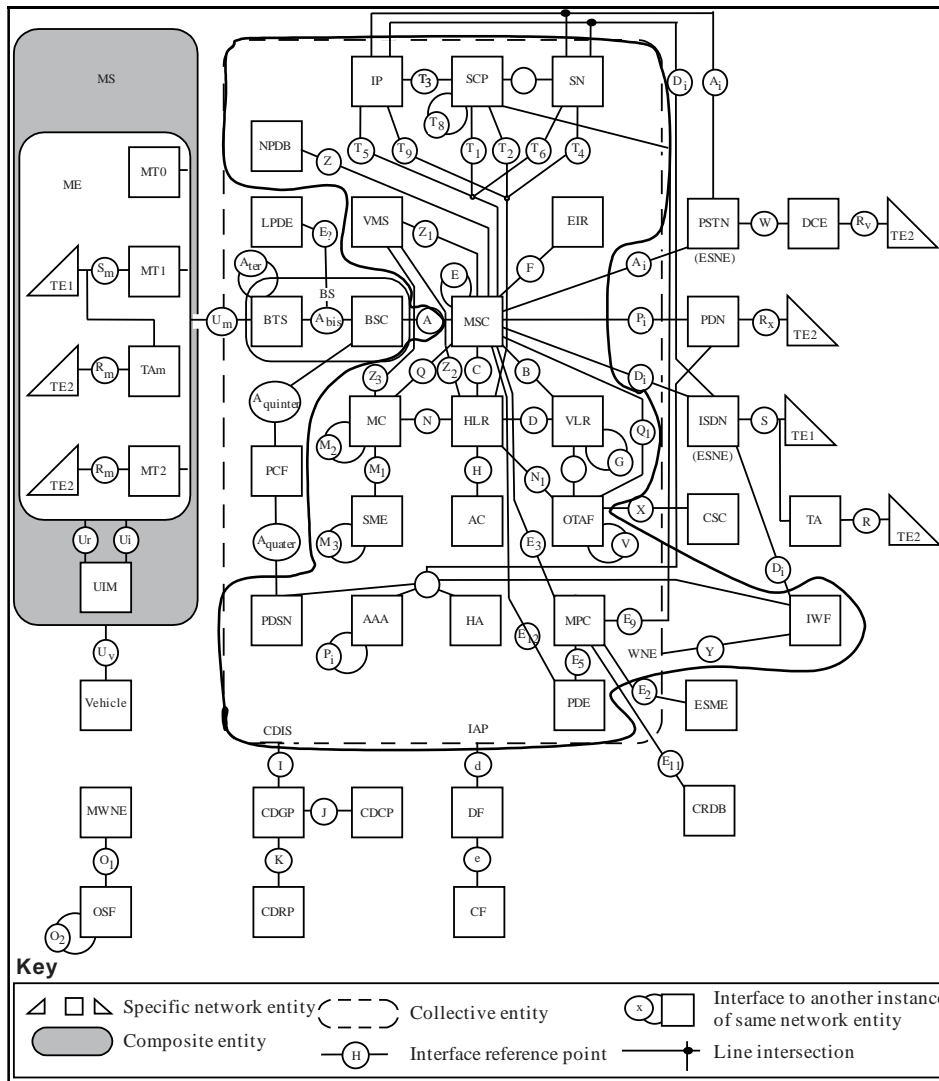
Global Trends-17

NOTE – The portion of the Figure within the solid line is the Core Network.

AAA	Authentication, Authorization and Accounting	**MC**	Message Center
AC	Authentication Center	**ME**	Mobile Equipment
BS	Base Station	**MPC**	Mobile Position Center
BSC	Base Station Controller	**MS**	Mobile Station
BTS	Base Transceiver System	**MSC**	Mobile Switching Center
CDCP	Call Data Collection Point	**MT**	Mobile Terminal
CDGP	Call Data Generation Point	**MWNE**	Managed Wireless Network Entity
CDIS	Call Data Information Source	**NPDB**	Number Portability DataBase
CDRP	Call Data Rating Point	**OSF**	Operations System Function
CF	Collection Function	**OTAF**	Over-The-Air Service Provisioning Function
CRDB	Coordinate Routing Data Base	**PCF**	Packet Control Function
CSC	Customer Service Center	**PDE**	Position Determining Entity
DCE	Data Circuit Equipment	**PDN**	Packet Data Network
DF	Delivery Function	**PDSN**	Packet Data Serving Node
EIR	Equipment Identity Register	**PSTN**	Public Switched Telephone Network
ESME	Emergency Services Message Entity	**SCP**	Service Control Point
ESNE	Emergency Services Network Entity	**SN**	Service Node
HA	Home Agent	**SME**	Short Message Entity
HLR	Home Location Register	**TA**	Terminal Adapter
IAP	Intercept Access Point	**TE**	Terminal Equipment
IIF	Interworking and Interoperability Function	**UIM**	User Identity Module
IP	Intelligent Peripheral	**VLR**	Visitor Location Register
ISDN	Integrated Services Digital Network	**VMS**	Voice Message System
IWF	Interworking Function	**WNE**	Wireless Network Entity
LPDE	Local Position Determining Entity	**WPSC**	Wireless Priority Service Center
LNS	L2TP Network Server		

In the Recommendation, the following Core Network Architecture Model are also explained other than the above reference model:

– IP MMD (Multimedia Domain)

– Packet Data Subsystem (PDS)

– IP Multimedia Session (IMS) Subsystem

3.3.3 Collaboration and Process in the Development of IMT Radio Interface Specifications

IMT is a system with global development activity and the IMT radio interface specifications identified in Recommendations ITU-R M.1457 for IMT-2000, ITU-R M.2012 for IMT-Advanced

and ITU-R M.2150 for IMT-2020 have been developed by the ITU in collaboration with the radio interface technology proponent organizations, global partnership projects and SDOs, and subsequently approved by the ITU Member States.

ITU-R has provided the global and overall framework and requirements, and has developed the core global specifications jointly with these organizations which are documented in Recommendations ITU-R M.1457, M.2012 and M.2150. Thus the detailed standardization has been undertaken within the recognized external organization[54], who transpose the global core specifications contained in those Recommendations into their own detailed published standards ensuring the global applicability and commonality of IMT.

This joint standardization approach is guided by ITU-R Resolution 9 (*Liaison and collaboration with other relevant organizations, in particular ISO and IEC*) and Resolution ITU-57 (*Principles for the process of development of IMT Advanced*).

ITU-R Resolution 57 has been the foundation for the creation of a set of well-defined procedures[55] in ITU-R to address the process and activities identified for the development of the IMT terrestrial components radio interface Recommendations[56]. This set of procedures includes announcement of a call for proposals for new radio interfaces and for updates to existing radio interfaces, the preparation of ITU-R Recommendations and Reports that define the minimum requirements for terrestrial IMT, the submission process, the evaluation process, and the development of the detailed radio interface specifications themselves. Detailed timelines are produced for each stage of the process.

Such an approach has led to effective and efficient collaboration with the relevant external organizations engaged in IMT and contributes positively to the planning, organization, and management of the work both in ITU-R and in the external organizations resulting in timely and on-going enhancements to IMT. This successful mechanism is already being utilized for the future development of IMT beyond that of IMT-Advanced in activities currently underway in ITU-R[57].

3.4   Techniques to facilitate roaming

Roaming is facilitated by:

1)   using the frequency bands identified for IMT in the Radio Regulations (RR);

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[54] A "recognized organization" in this context is defined to be a recognized SDO that has legal capacity, a permanent secretariat, a designated representative, and open, fair, and well-documented working methods.

[55] Web pages in ITU-R have been established to document the process for IMT-2000 submission and evaluation, the process for IMT-Advanced submission and evaluation and the process for IMT-2020 submission and evaluation associated with developing and/or revising the relevant ITU-R Recommendations for the terrestrial components of the IMT radio interfaces.

[56] The procedures defined in the "IMT-ADV" series of documents for IMT-Advanced in conjunction with ITU-R Resolution 57 have recently be applied to the on-going enhancement of IMT-2000 from year 2013 onwards as defined in the "IMT-2000" series of documents. The adoption of a common set of procedures for IMT-2000 and IMT-Advanced further improves and streamlines the work management both in ITU-R and in the relevant external organizations on IMT development.

[57] See "ITU towards IMT for 2020 and beyond".

2)	following the frequency arrangements in Recommendation ITU-R M.1036 – Frequency arrangements for implementation of the Terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR), (03/2012), which provides guidance on the selection of transmitting and receiving frequency arrangements for the terrestrial component of IMT;

3)	using the 3GPP operating band that are defined in Table 5.5-1 in the 3GPP TS 36.101 http://www.3gpp.org/ftp/Specs/archive/36_series/36.101/36101-c60.zip [2], in Table 5.0 in the 3GPP TS 25.101 http://www.3gpp.org/ftp/Specs/archive/25_series/25.101/25101-c60.zip [3] and section 5.2 in the Technical Specification 3GPP TS 25.102 http://www.3gpp.org/ftp/Specs/archive/25_series/25.102/25102-c00.zip [4][58]; and

4)	using the 3GPP2 operating band defined in Table 1.5-1 in the band class specification 3GPP2 C.S0057 http:/www.3gpp2.org/public_html/specs/C.S0057-E_v1.0_Bandclass Specification.pdf[5][59].

It should be noted that the technology used by a system and its conformance with the recommended specifications and standards in Recommendation ITU-R M.1457 define that system as IMT-2000, and Recommendation ITU-R M.2012 define that system as IMT-Advanced regardless of the frequency band of operation as explained in *considering k)* of Recommendation ITU-R M.1580. So it should be also noted that harmonized frequency arrangements for the bands identified for IMT are addressed in Recommendation ITU-R M.1036, which also indicates that some administrations may deploy IMT-2000 systems in bands other than those identified to IMT in the RR, as explained in *considering l)* of the same Recommendation mentioned above.

# 4	IMT spectrum

## 4.1	International spectrum identified for IMT

A number of frequency bands are identified for IMT in the Radio Regulations (RR). Recommendation ITU-R M.1036 provides guidance on the selection of transmitting and receiving frequency arrangements for the terrestrial component of IMT systems with a view to assisting administrations on spectrum-related technical issues relevant to the implementation and use of the terrestrial component of IMT in the bands identified in the Radio Regulations.

The following bands are identified for IMT in the Radio Regulations (RR) Edition 2020, as shown in Table 1. This identification does not preclude the use of these bands by any application of the services to which they are allocated or identified and does not establish priority in the Radio Regulations. It has to be noted that different regulatory provisions apply to each band. The Regional deviations for each band are described in the different footnotes applying in each band, as shown in Table 1.

TABLE 1

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[58] It should be noted that some bands standardized in 3GPP are not identified for IMT and not part of the Harmonized frequency arrangements of Recommendation ITU-R M.1036.

[59] It should be noted that some bands standardized in 3GPP2 are not identified for IMT and not part of the Harmonized frequency arrangements of Recommendation ITU-R M.1036.

Band	Footnotes identifying the band for IMT		
	Region 1	Region 2	Region 3
450-470 MHz	**5.286AA**		
470-698 MHz	–	**5.295, 5.308A**	**5.296A**
694/698-960 MHz	**5.317A**	**5.317A**	**5.313A, 5.317A**
1 427-1 518 MHz	**5.341A**, **5.346**	**5.341B**	**5.341C**, **5.346A**
1 710-2 025 MHz	**5.384A, 5.388**		
2 110-2 200 MHz	**5.388**		
2 300-2 400 MHz	**5.384A**		
2 500-2 690 MHz	**5.384A**		
3 300-3 400 MHz	**5.429B**	**5.429D**	**5.429F**
3 400-3 600 MHz	**5.430A**	**5.431B**	**5.432A, 5.432B, 5.433A**
3 600-3 700 MHz	–	**5.434**	–
4 800-4 990 MHz	**5.441B**	**5.441A, 5.441B**	**5.441B**
24.25-27.5 GHz	**5.532AB**		
37-43.5 GHz	**5.550B**		
45.5-47 GHz	**5.553A**	**5.553A**	**5.553A**
47.2-48.2 GHz	**5.553B**	**5.553B**	**5.553B**
66-71 GHz	**5.559AA**		

Also, administrations may deploy IMT systems in bands other than those identified in the RR, and administrations may deploy IMT systems only in some or parts of the bands identified for IMT in the RR.

4.2 Frequency arrangements

The frequency arrangements for IMT contained in Recommendation ITU-R M.1036 are provided with the intent of enabling the most effective and efficient use of the spectrum to deliver IMT services – while minimizing the impact on other systems or services in these bands – and facilitating the growth of IMT systems.

The recommended frequency arrangements for implementation of IMT in the bands listed in Table 1 are provided in the latest revision of Recommendation ITU-R M.1036[60] "Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)".

4.3 Methods to Estimate spectrum requirements for IMT

The methodology to estimate spectrum requirements for IMT is described in Recommendation ITU-R M.1768-1 – Methodology for calculation of spectrum requirements for the terrestrial component of IMT. Report ITU-R M.2290 – Future spectrum requirements estimate for terrestrial IMT, provides a global perspective on the future spectrum requirement estimated for terrestrial

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[60] http://www.itu.int/rec/R-REC-M.1036/en [61] The use of the term "IMT-2020" is a placeholder terminology and the specific nomenclature to be adopted for the future development of IMT is expected to be finalized at the Radiocommunication Assembly 2015.

IMT. The input parameters in this Report are not country specific. In some countries, the spectrum requirements can be lower than the low estimate and in some other countries, the spectrum requirements can be higher than the high estimate (see Annex 4 of Report ITU-R M.2290, Summary of national spectrum requirements in some countries). The methodology explained in the Recommendation and utilised in the Report could be used to estimate the total IMT spectrum requirements of a given country only if all the current input parameter values used in this report are replaced by the values which apply to that specific country (as described in the methodology itself).

There is a user guide on the methodology as "User guide for the IMT spectrum requirement estimation tool" in the ITU-R WP 5D web-page whose address is http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/Pages/default.aspx. As described in the guide, the methodology of estimating the spectrum requirements for IMT is implemented in MS Excel as a Spectrum Calculator tool to facilitate its use. The tool is also available under the "reference" of the ITU-R WP 5D web-page for users with TIES (Telecommunication Information Exchange Service) accounts.
The tool consists of 27 worksheets and seven modules of macros. The worksheets present input parameter values, intermediate calculation results obtained from worksheet calculations and macro calculations, and the final spectrum requirements. The tool is executed from its opening sheet called "Main", which is the core of the tool.

Figure 18 hereunder shows the relationship between the methodology flow chart and the corresponding worksheets in the "Spectrum Calculator" tool as well as the different input parameters to the methodology calculation steps. The worksheets with a grey background colour in Figure 18 denote the locations in the tool where the input parameter values are inserted. The worksheets with a white background colour in Figure 18 are where the actual calculation is implemented including intermediate calculation results. For further information please refer to the user guide.

FIGURE 18

**Input parameters, methodology flow chart and corresponding worksheets
in the "Spectrum Calculator" tool**
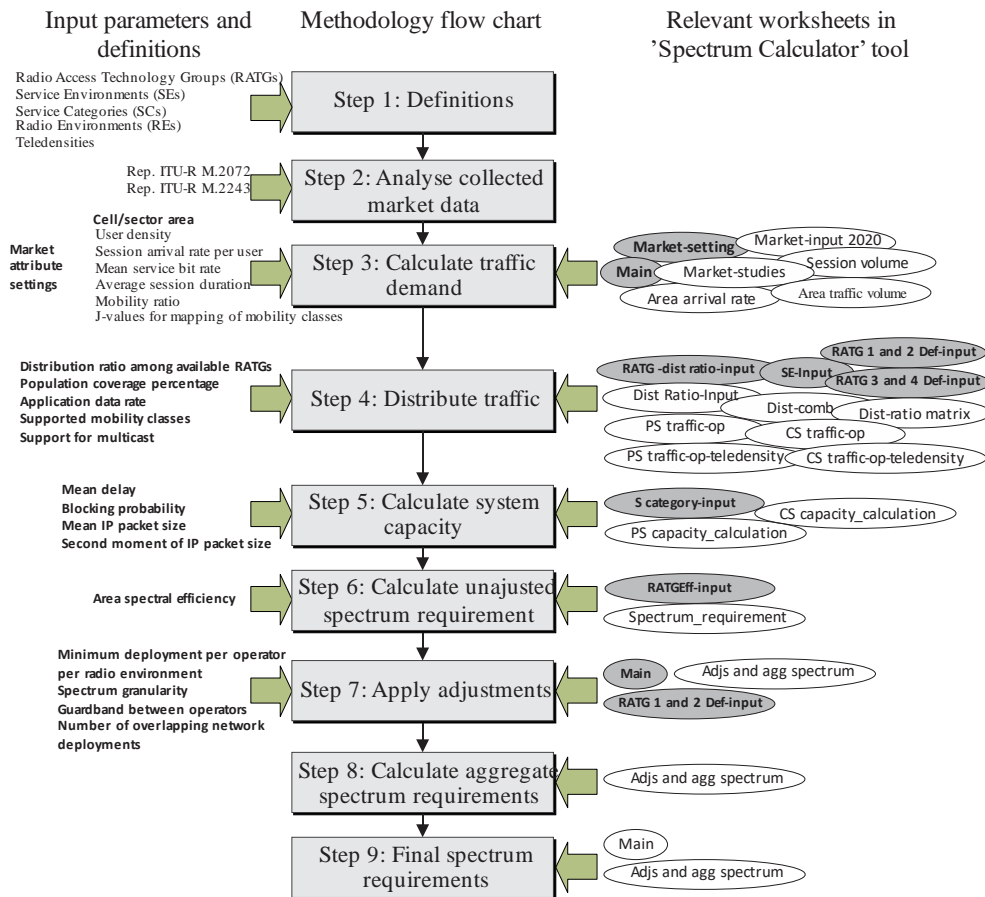
Global Trends-18

5   Regulatory issues

5.1   Institutional aspects and arrangements

To facilitate the successful deployment of IMT systems, the policy to make the spectrum available to the market should be clearly stated. In order to guarantee that the spectrum policy is aligned with the country's main objectives, it is important that telecommunications should figure on country's main agenda. In this way, regulators and other government institutions will have the necessary support to conduct their activities.

Another important aspect that can foster IMT deployment is related to the institution arrangements for policy delivery. The agency responsible for the spectrum policy should pay close attention to the role of each government agent (national and subnational) as well as other market stakeholders. It is also important to avoid responsibility overlap or gaps in order to facilitate the achievement of goals, diminish tension between institutions, and encourage agreements.

In addition, all stakeholders should have a clear understanding of the decision-making process. This could be accomplished through the development of a code of practice for the decision-making process, enabling both regulators and operators to have a clear understanding of how regulatory decisions are made, and any applicable processes for appealing such decisions.

5.2 Transparency and stakeholder involvement

In order to ensure that regulatory and policy decisions are made in the best interest of all, an open and public decision-making process should be used. This has two main benefits. First, by using a process that provides for public review and comment of proposed regulations and decisions, policymakers and regulators ensure that the regulatory and policy regime is not developed in a vacuum, and that current and expected future mobile market developments are considered. Policymakers, operators and vendors each have unique insights on the mobile market that, when considered together, have the best chance of developing a mobile sector based on international best practices and up-to-date market and technology intelligence.

Second, an open and public policy development process will lead to greater transparency, a key characteristic of any good decision-making process. By soliciting input from stakeholders and the public at large, and ensuring that industry plays a central role in the development of policies and priorities, regulators have an increased likelihood of crafting a regulatory and policy regime that is supported by most, if not all, interested parties. There are various approaches to including private sector stakeholders in the regulatory process, including standing advisory panels or groups, public consultations, and targeted solicitation of inputs, none of which are mutually exclusive. The close cooperation of regulators and industry is crucial to the development of a robust regulatory regime as well as a successful mobile industry.

5.3 Market knowledge

In order to develop good IMT spectrum policy, it is important for regulators and government institutions to know the actual market status and the community needs. To know the needs, the governments can conduct surveys, collect data through public consultations, and other feedback instruments that enable the market and the society to show their opinions and needs. This process can enhance government's decision making process, improving the effectiveness and quality of the public policies.

Besides, government agencies may also take into account cultural aspects, social conditions, and demographical disparities, since these aspects may influence the development of spectrum policy instruments.

5.4 Spectrum licensing

5.4.1 IMT licensing considerations

Many considerations may impact IMT licensing conditions including the following:
– Technology requirements
– Coverage/roll-out obligations
– Timing of license assignments
– Duration of licenses
– Spectrum block size
– Number of operators
– Infrastructure sharing
– Number portability.

5.4.2 IMT licensing principles and methods

Many methods of assigning spectrum licenses exist. These methods follow two approaches: 1) non-market based assignments such as comparative process (also known as beauty contests) and

lotteries 2) market-based approaches such as auctions. In cases of limited demand for a particular frequency band in a particular geographic area, first-come first served licensing may also be considered. Licensing is a national prerogative and each country must decide what methodology is appropriate for the conditions that exist within its legal, regulatory, and market framework.

To the maximum practical extend, spectrum should be licensed in alignment with regionally and internationally harmonized mobile spectrum bands to enable economies of scale, reduce cross-border interference and facilitate international services. Also, licensing authorities should publish roadmaps of the planned release of additional spectrum bands to maximize the benefits of spectrum use. A spectrum roadmap should take a long-term and holistic approach and include a comprehensive and reasonably detailed inventory of current use.

Furthermore, transferable and flexible spectrum rights may also be considered when assigning spectrum licenses. According to Report ITU-R SM.2012, "... economists recommend that spectrum users be allowed to transfer their spectrum rights (whether assigned by auction or some other assignment mechanism) and that spectrum users have a high degree of flexibility in the choice of the consumer services that they provide with their spectrum."

For more information on spectrum assignment methods, see section 2.3.1 of Report ITU-R SM.2012.

5.5 IMT spectrum clearing (including re-farming) guidelines

Recommendation ITU-R SM.1603-1 – Spectrum redeployment as a method of national spectrum management, gives guidelines for spectrum redeployment issues. This Recommendation defines spectrum redeployment (also known as spectrum re-farming) as "a combination of administrative, financial and technical measures aimed at removing users or equipment of the existing frequency assignments either completely or partially from a particular frequency band. The frequency band may then be allocated to the same or different service(s). These measures may be implemented in short, medium or long time-scales." The Recommendation also provides a guide for national consideration of redeployment issues.

5.6 Global circulation of terminals

The global circulation of terminals allows users to carry their personal terminals into a visited country and the ability to use them wherever possible. Recommendation ITU-R M.1579 establishes the technical basis for global circulation of IMT 2000 terrestrial terminals, based on terminals not causing harmful interference in any country where they circulate. Further information can be found in Recommendation ITU-R M.1579 – Global circulation of IMT-2000 terrestrial terminals.

5.7 Unwanted emissions

Information regarding unwanted emissions can be found in Recommendation ITU-R M.1580 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000, and Recommendation ITU-R M.1581 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000. In addition, information on IMT-Advanced can be found in Recommendation ITU-R M.2070 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced, and Recommendation ITU-R M.2071 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-Advanced.

6 Steps to consider in the deployment of IMT systems

6.1 Key issues and questions to be considered prior to IMT network deployment

Key issues to be considered are as follows:

– Spectrum Harmonization

– Maturity of the technology to be introduced

– Device availability and affordability

– Market trends

– Radio Interface standards referring to ITU-R Recommendations and Reports

– Demographics and services (e.g. support of new services and applications)

– Time frame for transition

– Assistance to customer in changeover to new technology

– Compatibility with incumbent telecommunication systems.

6.2 Migration of existing wireless systems to IMT

6.2.1 Migration strategy

There are some issues to be considered when planning the migration from GSM to IMT. These issues are as follows:

– Amount of existing wireless system (e.g. GSM) spectrum available

– Traffic balance between low band (e.g. GSM 850/900 MHz) and high band (e.g. GSM – 1 800/1 900 MHz)

– Solutions to increase GSM's network capacity: Voice services over Adaptive Multi-user channels on One Slot (VAMOS), Orthogonal Sub-channels (OSC), tight frequency reuse, etc.

– Voice traffic migration to IMT (e.g. UMTS/LTE)

– Re-farming technology decisions (e.g. Introduction of HSPA/LTE to GSM 850/900 MHz and GSM 1 800/1 900 MHz)

– Re-farming roadmap (e.g. gradual introduction of IMT to GSM bands or re-farming of both GSM 850/900 MHz and GSM 1 800/1 900 MHz at the same time).

6.2.2 General migration process

The Spectrum migration consists of a solution which reduces the spectrum needed to a desired limit without compromising on performance of the existing network, which can be structured in five phases and activities as outlined below and summarized in Figure 19.

FIGURE 19

Spectrum Migration Solution overview

Feasibility study	Proposal on best frequency plan strategies to adopt Needed actions before carving
Pre-refarming actions	Set best possible baseline scenario for spectrum carve and UMTS introduction (traffic balancing, RF optimization)
Refarming	Provide Optimum Frequency Plan balancing network performance and future ROI
Post-refarming actions	Improve network performance in new challanging scenario (HO optimization)
Performance assessment	Monitoring and final report

Global Trends-19

Feasibility Study

The main target of this phase is to evaluate if the migration can be done within the acceptance criteria (i.e. agreed KPI levels for amount of spectrum to be released). The first task is to define the required spectrum reduction, typically dependent on the following factors:

– Operator restrictions

– Maturity of the network

– Expected traffic growth

– Network evolution

Pre Re-farming actions

In this phase, using output from the feasibility study, a complete set of actions will be proposed in order to establish the best baseline scenario for the implementation of a new frequency plan after the spectrum carving. These actions typically includes RF Optimization and RRM Optimization.

There are several functions which can be used to aid in the achievement of the objectives (capacity, interference and traffic management). These functions will reduce the interference levels or improve the network's ability to cope with the increased interference.

Frequency Plan elaboration and implementation

In this phase the final frequency will be implemented guided by the strategies defined in the previous phase. This phase includes the following parts:

– Frequency Plan

– Updated Neighbour List

– Fall-back plan

• Fall back to the previous frequency plan

• A fast reactive process to identify and troubleshoot the worst performing sectors

Post Re-farming actions

A second round of optimization actions may be proposed after the implementation of the Re-farmed frequency plan. In order to understand the real scope of this phase, a Performance Analysis must be carried for two main reasons:

–   Ensure no severe degradation is present post-Re-farming. If this is the case, then a fall-back plan will be auctioned.

–   Acknowledge the necessary actions to be carried out in order to meet the agreed Acceptance criteria.

Performance Assessment

After Implementation, the network will be monitored mainly through the Operational Support Systems (OSS)-based tool. Other tools may be also utilized for specific monitoring tasks.

6.2.3   Some Case Studies

Operators in Europe and Asia are re-farming parts of their GSM spectrum to allow new technology introduction. The general trend has been to re-use 900 MHz for IMT-2000 and 1 800 MHz for IMT. The driver for IMT-2000 in 900 MHz is to improve coverage since low frequency spectrum has better coverage characteristics compared with the higher frequencies thereby allowing both deeper and broader coverage. The device eco-system for 900 MHz is also very strong.

In many markets, the motivation for deploying IMT in their existing 1800 MHz band is a combination of capacity relief and to demonstrate market leadership by launching IMT services before new spectrum, such as 2600 MHz, is available. The device eco-system for IMT in 1 800 is also very strong, particularly at the high end of the market.

6.2.3.1   General Scenarios

The ultimate arrangement that mobile broadband networks will take, will vary from case to case. As an illustration of the possible alternative routes that could be taken by three different operators, Figures 20 and 21 show the start points and end points of the evolution to a high-performance mobile broadband network using different radio-access technologies.

FIGURE 20

Starting frequency band allocation and technology deployment for the operator
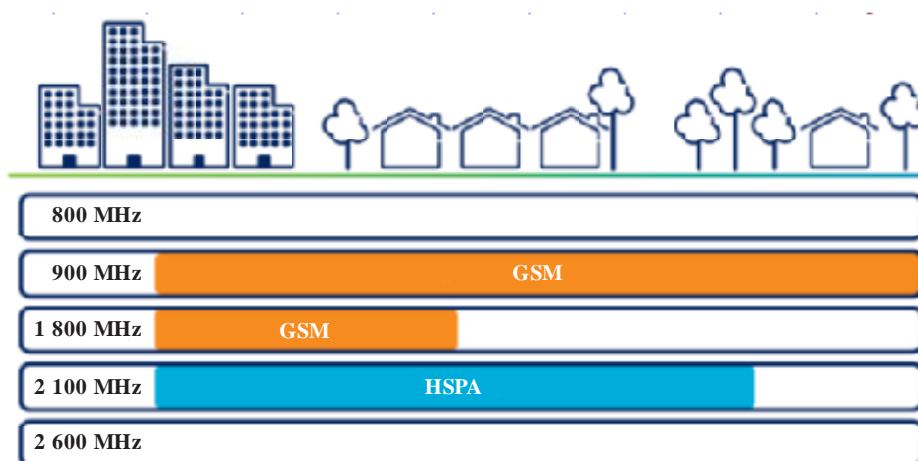
Global Trends-20

FIGURE 21

Evolved frequency band allocation and deployment for the operator
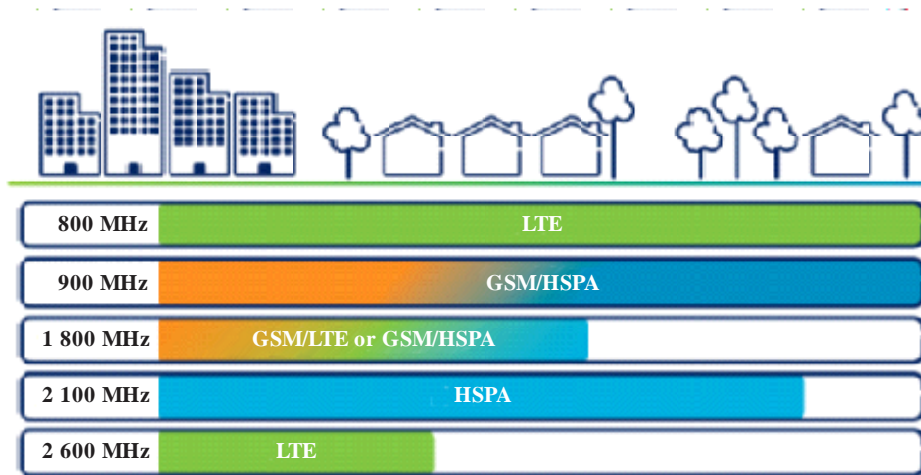
Global Trends-21

Typical European frequencies are used to illustrate the strategies for this evolution.

Scenario 1: This operator has no early access to either 2600 MHz or 800 MHz spectrum for IMT (e.g. LTE). Here, the first step is to re-farm the 900 MHz spectrum to IMT-2000 (e.g. HSPA) in order to boost IMT-2000 coverage and capacity, especially in rural areas. As GSM traffic diminishes as a result of the greater IMT-2000 (e.g. HSPA) capacity, the operator can re-farm the 1800 MHz spectrum either for IMT (e.g. LTE) or IMT-2000 (e.g. HSPA) to provide high-performance mobile broadband in urban and suburban areas. The technology choice will depend on the operator's market position, the current and projected device fleet, the ability to serve mass-market volumes of IMT-2000 (e.g. HSPA) smartphones in existing 3GPP bands, and the availability of other bands for IMT (e.g. LTE). In this scenario, the operator is able to roll out IMT (e.g. LTE) in other bands as it becomes available.

Scenario 2: This operator has already deployed IMT-2000 (e.g. WCDMA/HSPA) in the 900 MHz, as well as in the 2100 MHz band. The total spectrum in these deployments is sufficient to cater for mass IMT-2000 (e.g. HSPA) smartphone uptake. By driving the uptake of IMT-2000 capable devices that use IMT-2000 access for voice and data, and rolling out GSM efficiency improvements, GSM traffic can be served within the 900 MHz spectrum. This frees up the 1800 MHz spectrum for IMT (e.g. LTE) deployment.

Scenario 3: This operator has early access to 2600 MHz spectrum for IMT (e.g. LTE), as well as the option for rolling out IMT (e.g. LTE) in the Digital Dividend 800 MHz band (made available following the shutdown of Europe's analogue TV networks). The operator's first step is to re-farm 900 MHz spectrum to IMT-2000 (e.g. WCDMA/HSPA) to provide wider and deeper IMT-2000 coverage and capacity, especially for rural and indoor areas. Increasing use of IMT-2000 (e.g. WCDMA/HSPA) in the wide area gradually reduces load on the GSM/EDGE network.

In addition, the operator deploys IMT (e.g. LTE) in the 2600 MHz band in urban hotspots to provide a high-speed mobile-broadband service to complement the IMT-2000 (e.g. HSPA) access. After this, the operator rolls out IMT (e.g. LTE) in the 800 MHz band to provide high-performance broadband in the wide area, including rural areas.

Ultimately, when GSM traffic has diminished significantly, the operator can re-farm the 1800 MHz spectrum for IMT (e.g. LTE) as well to provide a further capacity and boost coverage.

Alternatively, if the need for additional IMT-2000 (e.g. HSPA) capacity is more pressing at this time, the operator has the option of deploying IMT-2000 (e.g. HSPA) in the 1800 MHz spectrum.

6.2.3.2   One example of Network Migration to LTE 1800

One operator in Australia's key strategies following the 2006 launch of its WCDMA network was a concerted effort to move GSM users to the new network. Many factors lay behind this strategy, including network rationalization, coherent branding and operational efficiency. To provide incentives for users to move to IMT-2000, the operator relied on a variety of options, such as free handset upgrades and attractive "no premium" pricing plans. As users moved to more advanced technology, they became more likely to adopt new services. But perhaps the most significant outcome was operator's ability to "empty" its GSM network and re-farm the 1 800 MHz spectrum to launch Australia's first LTE network in September 2011.

Since the network launch, the volume of traffic in this operator's mobile network has doubled every year. In late 2010, through a capacity modelling tool, the operator forecast that the network capacity would run out before the new 700 MHz spectrum – primed for LTE – became available. So something had to be done – and fast.

Spectrum re-farming was not new to this operator. It had already successfully introduced WCDMA on re-farmed 850 MHz and built a healthy ecosystem in the process. In pioneering a global 1 800 MHz LTE ecosystem, the operator took the same approach, playing an active role by working in conjunction with infrastructure suppliers, device and chipset manufacturers and industry bodies. Today, 1 800 MHz has become the most popular LTE band worldwide.

When this operator launched the nation's first LTE network, it was seen by industry observers as a six month head start on competitors that could consolidate the company's already dominant position. The launch was as much a result of the operator's engineering strategy as of its business strategy.

For additional information related to the migration please refer to Annex I – Technology migration in a given frequency band.

6.2.3.3   Example of Network Migration to IMT in 900 MHz band

In Viet Nam, UMTS systems have been deployed in the 2 100 MHz band. Due to high deployment cost of the UMTS 2 100 MHz in rural areas of Viet Nam, mobile broadband services in these areas were not adequate. Recently, operators showed strong demand to deploy mobile broadband systems in GSM 900 MHz band for rural coverage mainly because of excellent propagation characteristic and low deployment cost. As GSM 900 MHz systems have national coverage, it is quite efficient to reuse the existing infrastructure for IMT systems in the same band.

The requests from operators triggered re-assessment of frequency planning from the Ministry of Information and Communications as Frequency Planning for this band is for GSM systems only. Operators were notified that the Ministry would re-consider the planning for 900 MHz band. Operators holding licenses in the 900 MHz band were allowed to carry out IMT systems trials in small scale in the same band. Operators chose to trial UMTS in the 900 MHz.

Operators' trial report showed excellent UMTS coverage, comparable data service with UMTS service in 2 100 MHz band, and all Key Performance Indicators were met.

Measurements of the quality of the existing GSM service indicated that there was no degradation in GSM's voice services.

At the same time, the Ministry had comprehensively studied the planning of 900 MHz band for IMT. The result was that it would be beneficial to the society as a whole, especially for rural areas,

to deploy IMT in 900 MHz band. The Ministry distributed public request for comment of the new policy and organized workshop to have operators' opinion.

With the success of operators' trial results and consensus responses of stakeholders, the Ministry enforced a new circular to allow the operators holding 900 MHz license to deploy IMT system in the same band.

The Ministry also informed the operators with the intention of long term frequency arrangement for IMT 900 MHz following 5 MHz blocks plan.

The operators were directed to follow the 5 MHz block plan as much as practical to avoid unnecessary cost and rearrangement issues in the future.

Figure 22 illustrates the IMT carrier arrangement in the 900 MHz band co-existing with GSM.

FIGURE 22

Example of re-farming 900 MHz band in the transition phase
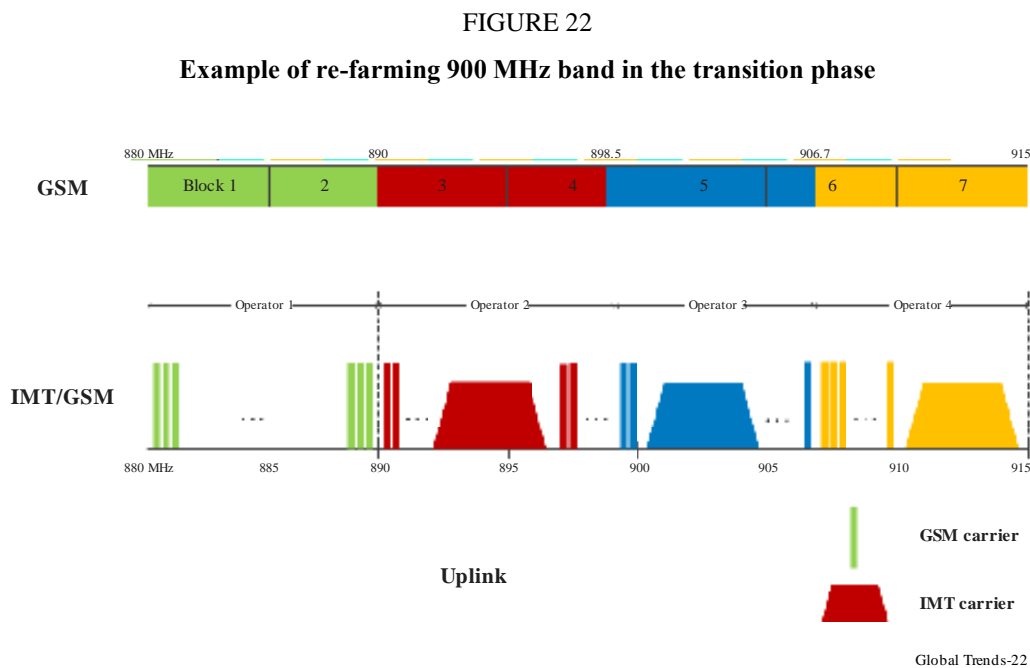
6.3   Choice of technology in the identified IMT bands

6.3.1   IMT Technology Considerations

It is important to consider bandwidth, coverage and capacity requirements when intending to implement a new IMT system. Considering various deployment possibilities, aggregation of spectrum used separately for FDD or TDD operations may be an efficient method to increase the utilization of the spectrum resource. FDD and TDD aggregation needs to be able to operate in the following scenarios:

–   Multiple carriers on co-located sites, part of which are FDD carriers and the rest are TDD carriers.

–   Different types of carriers on different sites, e.g. FDD carrier on macro sites, and TDD carriers on small cells.

For development of systems that can support FDD and TDD aggregation, techniques must be developed to enable legacy user equipment (UE) that operates on either FDD or TDD networks to be able to work on the FDD-TDD aggregated network. Eventually future-evolved UE that support FDD and TDD aggregation could enjoy the increased peak data rate.

For more information on criteria leading to technology decisions, please refer to section 7.

6.3.2 Satellite component of IMT

IMT consists of both terrestrial component and satellite component radio interfaces. The terrestrial and satellite components are complementary, with the terrestrial component providing coverage over areas of land mass with population density considered to be large enough for economic provision of terrestrially-based systems, and the satellite component providing service elsewhere by a virtually global coverage, especially with strength in providing coverage in the sea, islands, mountainous districts, and sparsely-populated areas. The ubiquitous coverage of IMT can therefore be realized using a combination of satellite and terrestrial radio interfaces.

The satellite component of IMT encompasses both IMT-2000 and IMT-Advanced. The radio interfaces for the satellite component of IMT-2000 are identified in Recommendation ITU-R M.1850-1, including:

–   Satellite radio interface A (SRI-A)

–   Satellite radio interface B (SRI-B)

–   Satellite radio interface D (SRI-D)

–   Satellite radio interface E (SRI-E)

–   Satellite radio interface F (SRI-F)

–   Satellite radio interface G (SRI-G)

–   Satellite radio interface H (SRI-H).

The radio interfaces for the satellite component of IMT-Advanced have been developed by ITU-R. Two radio interfaces are identified:

–   BMSat

–   SAT-OFDM.

For more information on radio interfaces for the satellite component of IMT-Advanced, please refer to Recommendation ITU-R M.2047 – Detailed specifications of the satellite radio interfaces of International Mobile Telecommunications-Advanced (IMT-Advanced), and to Report ITU-R M.2279 – Outcome of the evaluation, consensus building and decision of the IMT-Advanced satellite process (Steps 4 to 7), including characteristics of IMT-Advanced satellite radio interfaces.

The specifications of the radio interfaces for the satellite component of IMT could also be adopted by other MSS systems and applied in other bands for MSS.

6.4 Deployment planning

A key to supporting the increasing data requirements of IMT systems is the provision of sufficient backhaul capacity to avoid the creation of a bottleneck. Fibre and wireless systems both have roles to play in backhaul of IMT data. Fibre has a greater capacity and typically lower operating expenses, while wireless backhaul is quicker and easier to install, especially in the case where many small cells are being connected. In addition, wireless technologies have the potential to provide lower latencies given the difference in propagation speeds between fibre and wireless. Although the proportion of data traffic backhauled by fibre is increasing, the absolute number of fixed wireless backhaul links is nevertheless increasing rapidly, particularly systems comprising a small number of hops in support of small mobile cells in urban and other high usage areas.

For more detailed information on the design of wireless backhaul systems please refer to Annex D – Description of Wireless Backhaul Systems.

7   Criteria leading to technology decisions

7.1   Spectrum implications, Channelization and Bandwidth considerations

The current availability of frequency bands and amount of bandwidth differs across Member States and regions and this leads to many challenges such as roaming, device complexity, lack of economics of scale, and interference. It is recognized that finding and assigning contiguous, broader and harmonized frequency bands which are aligned with future technology development can reduce these challenges.

Also, pursuing greater harmonization with larger contiguous frequency bands will support continued introduction of mobile devices with longer battery life while improving spectrum efficiency; and potentially reducing cross border interference.

Flexible spectrum usage can provide technical solutions to address the growing traffic demand in the future and allow more efficient use of radio resources including the limited spectrum resources. Flexible spectrum usage can improve the frequency efficiency, which includes aspects such as cognitive radio techniques, Authorized Shared Access (ASA), and joint management of multiple radio access technologies (RATs).

7.2   Importance of multi-mode/multi-band solutions

The increasing availability of multi-radio mobile devices has fuelled a growing trend towards exploiting multiple RATs to address capacity as well as connectivity limitations. Integration of multiple radio access technologies could help seamlessly integrate the new spectrum bands, existing licensed bands, and unlicensed bands to meet capacity and service demands and provide better user experience.

Multi-radio networks also offer an opportunity for future IMT systems to support all footprints: wide area networks (WANs), local area networks (LANs), and personal area networks (PANs) in a fashion that is transparent to the end user.

7.3   Technology development path

ITU-R WP 5D has a process in place to continually revise Recommendations ITU-R M.1457, ITU-R M.2012 and ITU-R M.2150 as several technologies have and will continue to introduce technological advancements to both established and more recent IMT systems. Member States can follow these advancements in many ways including tracking the latest revisions of these Recommendations. Advances in the mobile industry have been significant over the past decade and the ability to introduce these technologies advancements quickly have contributed to the significant growth in mobile broadband data usage. ITU-R WP 5D has also started working on a new Recommendation to lay down a vision for the next generation of IMT towards 2030.

7.4   Backhaul Considerations

In this context backhaul means the aggregate of all the traffic being transported to the core network. As traffic demands for mobile broadband communications increases, backhaul is increasingly becoming an important infrastructure in the IMT network architecture that requires special consideration. Backhaul performance not only affects the data throughput available to users, but also the overall performance of the radio-access network.
High performance backhaul with low latency enables tighter coordination between nodes, which in turn uses available spectrum more efficiently. Networks with large numbers of (small) cell sites require backhaul solutions that can use a selection of physical transmission media, including microwave, fibre and wireless connectivity.

Backhaul solutions should not limit the radio access network, which means that there should be adequate backhaul capacity provision at the network cell sites. In addition, backhaul solutions should have sufficient end-to end performance to meet the desired user quality of experience (QoE) everywhere for the provision of mobile broadband.

7.5 Technology Neutrality

With the rapid changes and developments occurring in the mobile sector, a technology neutral approach in developing policies and regulations for the wireless communications sector will support the continued and robust growth of mobile broadband which will directly benefit the entire community, both the public and private sectors. Policies and regulations that mandate or only address specific technology solutions frequently become impediments for continued growth, limit competition and stifle innovation.

ANNEX A

Abbreviations, acronyms, interface and reference points

A.1   Abbreviations and acronyms

ACI   Adjacent Channel Interference

ACLR   Adjacent Channel Leakage Ratio

ACS   Adjacent Channel Selectivity

A-GPS   Assisted GPS

ANSI   American National Standard Institute

ARIB   Association of Radio Industries and Businesses

ATIS   Alliance for Telecommunications Industry Solutions

AuC   Authentication centre

B2B   Business to Business

BCCH   Broadcast Control Channel

BSC   Base Station Controller

BSSAP   Base Station Subsystem Application Part

BSS   Base station system

BTS   Base Transceiver Station

CAGR   Compound annual growth rate

CCSA   China Communications Standards Association

CDMA   Code Division Multiple Access

CEPT   European Conference of Postal and Telecommunications Administrations

CGI   Computer-generated imagery

CGI   Cell Global Identifier

CI   Cell Identity

CID   Cell ID

CN   Core network

CS-MGW   Circuit switched – Media gateway function

DCCH   Dedicated Control Channel

CDR   Call-detail Record

DECT   Digital Enhanced Cordless Telecommunications

DL   Downlink

DME   Distance Measuring Equipment

EDGE   Enhanced Data rate for GSM Evolution

EGPRS   Enhanced GPRS

eHRPD	Evolved High Rate Packet Data
EHS	Electromagnetic Hyper Sensitivity
EIA	Electronic Industries Association
E interface	mobile switching centre server (MSC server) – mobile switching centre server (MSC server)
EIR	Equipment Identity Register
eNB	enhanced Node B
EPC	Evolved Packet Core
E-SMLC	Evolved Serving Mobile Location Center
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GGSN	Gateway GPRS Support Node
GMLC	Gateway Mobile Location Center
GMSC	Gateway mobile Switching Center
GPRS	General Packet Radio System / General Packet Radio Service
GPS	Global Positioning System
GSA	Global Mobile Suppliers Association
GSM	Global System for Mobile Communications
GSMA	GSM Association
GT	Global Title
HLR	Home Location Register
HPCRF	PCRF in the home PLMN
HRPD	High Rate Packet Data
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
ICIC	Inter-Cell Interference Coordination
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IOS	Interoperability Specification
IP	Internet Protocol
ISO	International Organization for Standardization
IWU	Interworking Unit

KPI	Key Performance Indicator
LAC	Location Area Code
LBS	Location Based Services
L-DACS	L-band Digital Aeronautical Communication
LLC	Logical Link Control
LMH-BWA	Land Mobile (including Wireless Access) – Volume 5: Deployment of Broadband Wireless Access Systems
LMU	Location Measurement Unit
LTE	Long Term Evolution
MAC	Medium Access Controller
MC	Multi-Carrier
MCC	Mobile Country Code
MCL	Minimum Coupling Loss
ME	Mobile Equipment
M2M	Machine-to-Machine
MME	Mobility Management Entity
MNC	Mobile Network Code
MSC	Mobile Switching Centre (also appears as "Mobile-services Switching Centre")
MSCe	Mobile Switching Centre emulation
NAS	Non-Access-Stratum
NMR	Network Management Reports
OECD	Organization for Economic Co-operation and Development
OFDMA	Orthogonal Frequency Division Multiple Access
O&M	Operation and Maintenance
OOBE	Out-Of-Band Emission
OSC	Orthogonal Sub-channels
OSI	Open System Interconnection
OSS	Operational Support Systems
O-TDOA	Observed Time Difference of Arrival
PB	Petabyte
PCRF	Policy and Charging Rules Function
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PDN GW	gateway which terminates the SGi interface towards the PDN
PHY	Physical Layer

PLMN	Public Land Mobile Network
PPDR	Public Protection and Disaster Relief
PS	Packet Switched
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RBS	Radio Base Station
RF	Radio Frequency
RFPM	RF Pattern Printing
RIT	Radio Interface Technology
RLC	Radio Link Controller
RNC	Radio Network Controller
RNS	Radio Network Subsystem (also appears as "Radio Network System")
RR	Radio Regulations
RRC	Radio Resource Controller
RRM	Radio Resource Management
RSVP	Resource Reservation Protocol
RTT	Radio Transmission Technologies
RTT	Round Trip Time
SDO	Standard Development Organization
SDU	Selection/Distribution Unit; Service Data Unit
SGSN	serving GPRS support node
S-GW	Serving Gateway
SIM	GSM Subscriber Identity Module; Specialised Information Model
SLP	SUPL Location Platform
SMLC	Serving Mobile Location Centre
SMS	Short Message Service
SMS-GMSC	SMS gateway MSC
SMS-IWMSC	SMS Interworking MSC
STP	Signalling Transfer Point
SUPL	Secure User Plane Location
TA	Timing Advance
TCH	Traffic Channel
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TDMA-SC	Time Division Multiple Access – Single Carrier

TD-SCDMA	Time Division Synchronous CDMA
TIA	Telecommunications Industry Association
TOM	Tunnelling Of Messages
TTA	Telecommunications Technology Association
TTC	Telecommunication Technology Committee
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
USIM	Universal Subscriber Identity Module
U-TDOA	Uplink Time Difference of Arrival
UTRAN	Universal Terrestrial Radio Access Network
UWC	Universal Wireless Communications Consortium
VAMOS	Voice services over Adaptive Multi-user channels on One Slot
VLR	Visitor location register
VPCRF	PCRF in the visited PLMN
WCDMA	Wideband CDMA
WMAN	Wireless Metropolitan Area Networking

A.2 Interface

A   mobile switching centre (MSC) – base station system (BSS)

A*bis*   base station controller (BSC) – base transceiver station (BTS)

A1   carries signalling information between the call control and mobility management functions of the circuit-switched MSC and the call control component of the BS (BSC).

A1p   carries signalling information between the call control and mobility management functions of the MSCe and the call control component of the BS (BSC).

A2   provides a path for user traffic and carries 64/56 kbps PCM information (for circuit-oriented voice) or 64 kbps Unrestricted Digital Information (UDI, for ISDN) between the Switch component of the circuit-switched MSC and the Selection/Distribution Unit (SDU) function of the BS.

A2p   provides a path for packet-based user traffic sessions and carries voice information via IP packets between the MGW and the BS.

A3   transports user traffic and signalling for inter-BS soft/softer handoff when a target BS is attached to the frame selection function within the source BS.

A5   provides a path for user traffic for circuit-oriented data calls between the source BS and the circuit-switched MSC.

A7   carries signalling information between a source BS and a target BS for inter-BS soft/softer handoff.

A8   carries user traffic between the BS and the PCF.

A9   carries signalling information between the BS and the PCF.

A10   carries user traffic between the PCF and the PDSN.

A11	carries signalling information between the PCF and the PDSN
B	an internal interface defined for modelling purposes
C	Gateway mobile switching centre server (GMSC server) – Home location register (HLR)
D	visitor location register (VLR) – home location register (HLR)
F	mobile switching centre server (MSC server) – equipment identity register (EIR)
G	visitor location register (VLR) – visitor location register (VLR)
G_b	serving GPRS support node (SGSN) – base station system (BSS)
G_c	home location register (HLR) – gateway GPRS support node (GGSN)
G_d	interface between the SGSN and the SMS Gateway
G_f	equipment identity register (EIR) – serving GPRS support node (SGSN)
G_n	gateway GPRS support node (GGSN) – serving GPRS support node (SGSN)
G_p	serving GPRS support node (SGSN) – external data network
G_r	home location register (HLR) – serving GPRS support node (SGSN)
G_s	mobile switching centre (MSC)/visitor location register (VLR) – serving GPRS support node (SGSN)
G_{xc}	S-GW – PCRF/VPCRF
Iu	communication interface between the RNC and the Core Network Interface (Mobile switching centre and Serving GPRS Support Node).
Iub	RNC – Node B
IuCS	mobile switching centre (MSC) – RNS or BSS
IuPS	serving GPRS support node (SGSN) – RNS or BSS
Iur	A logical interface between two RNC whilst logically representing a point-to- point link between RNC, the physical realization may not be a point-to-point link.
Lb/Iupc	interface between SMLC and RSC/RNC
Lg/SLg	interface between GMLC and MSC/MME
Lh/SLh	interface between GMLC and HLR/HSS
S1	standardized interface between eNB – the Evolved Packet Core (EPC).
S1-MME	MME – E-UTRAN
S1-u	interface connecting the eNB to the S-GW by means of the user-plane part
S1-c	interface connecting the eNB to the MME by means of the control-plane part
S3	MME – SGSN
S4	S-GW – SGSN
S5	S-GW – PDN GW
S6a	MME – HSS
S6d	home location register (HLR) – serving GPRS support node (SGSN)
S8	S-GW – PDN GW S8 (the inter-PLMN variant of S5)
S9	HPCRF – VPCRF
S10	MME – MME
S11	MME – S-GW

SLs   interface between E-SMLC and MME

Um   air interface between BTS and MS

Uu   Radio interface between UTRAN and the user equipment

X2   supporting the exchange of signalling information between two eNBs, and mainly used to support active-mode mobility.

A.3   Reference point

B   interface between MSC and the VLR

C   interface between the MSC and the HLR

D   interface between the VLR and HLR

d   interface between an IAP and the DF

D_1 interface between the OTAF and the VLR

D_i interface between:

    –   The IP and the ISDN

    –   The IWF and the ISDN

    –   The MSC and the ISDN [ESBE]

    –   The SN and the ISDN

E   interface between the MSC and the MSC

E_3 interface between the MPC and the MSC

E_5 interface between the MPC and the PDE

E_9 interface between the MPC and the SCP

E_{11} interface between the CRDB and the MPC

E_{12} interface between the MSC and the PDE

e   interface between the CF and the DF

F   interface between the MSC and the EIR

G   interface between the VLR and the VLR

G_i GGSN – packet data networks

G_x PCEF – PCRF/H-PCRF/V-PCRF

H   interface between the HLR and the AC

I   interface between the CDIS and the CDGP

J   interface between the CDGP and the CDCP

K   interface between the CDGP and the CDRP

M_1 interface between the SME and the MC

M_2 MC to MC interface

M_3 SME to SME interface

M_c mobile switching centre server (MSC Server) –circuit switched media gateway (CS-MGW)

N   interface between the HLR and the MC

N_1 interface between the HLR and the OTAF

N_b circuit switched media gateway (CS-MGW) – circuit switched media gateway (CS-MGW)

N_c mobile switching centre server (MSC server) –gateway mobile switching centre server (GMSC server)

O_1 interface between an MWNE and the OSF

O_2 interface between an OSF and the OSF

P_i interface between:

  –   The AAA and the AAA,

  –   The AAA and the PDN,

  –   The IWF and the PDN,

  –   The MSC and the PDN, plus

  –   The PDSN and the PDN.

Q   interface between the MC and the MSC

Q_1 interface between the MSC and the OTAF

R_x the application function – the policy and charging rule function (PCRF)

S12   S-GW – UTRAN

S13   MME – EIR

SG_i PDN GW – packet data networks

T_1 interface between the MSC and the SCP

T_2 interface between the HLR and the SCP

T_3 interface between the IP and the SCP

T_4 interface between the HLR and the SN

T_5 interface between the IP and the MSC

T_6 interface between the MSC and the SN

T_7 interface between the SCP and the SN

T_8 interface between the SCP and the SCP

T_9 interface between the HLR and the IP

V   interface between the OTAF and the OTAF

X   interface between the CSC and the OTAF

Y   interface between a Wireless Network Entity (WNE) and the IWF

Z   interface between the MSC and the NPDB

Z1   interface between the MSC and the VMS

Z2   interface between the HLR and the VMS

Z3   interface between the MC and the VMS

ANNEX B

Reference publications

B.1   ITU publications

B.1.1   ITU Recommendations

Terrestrial IMT (and other, related) Recommendations:

–   Recommendation ITU-R M.678 – International Mobile Telecommunications-2000 (IMT-2000)

–   Recommendation ITU-R M.819 – International Mobile Telecommunications-2000 (IMT-2000) for developing countries

–   Recommendation ITU-R M.1036 – Frequency arrangements for implementation of the Terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR) (03/2012)

–   Recommendation ITU-R M.1224 – Vocabulary of terms for International Mobile Telecommunications (IMT)

–   Recommendation ITU-R M.1457 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

–   Recommendation ITU-R M.1580 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT 2000

–   Recommendation ITU-R M.1581 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT 2000

–   Recommendation ITU-R M.1579 – Global circulation of IMT-2000 terrestrial terminals

–   Recommendation ITU-R M.1645 – Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

–   Recommendation ITU-R M.1768 – Methodology for calculation of spectrum requirements for the future development of IMT-2000 and systems beyond IMT-2000

–   Recommendation ITU-R M.1801 – Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz

–   Recommendation ITU-R M.1822 – Framework for services supported by IMT

–   Recommendation ITU-R M.1850 – Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)

–   Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)

For more information please refer to: List of ITU-R Recommendations on IMT.

B.1.2   ITU Reports

Terrestrial IMT (and other, related) Reports

–   Report ITU-R M.2038 – Technology trends (as they relate to IMT-2000 and systems beyond IMT-2000)

–   Report ITU-R M.2039 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses

–	Report ITU-R M.2242 – Cognitive radio systems specific for IMT systems

–	Report ITU-R M.2243 – Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications

–	Report ITU-R M.2072 – World mobile telecommunication market forecast

–	Report ITU-R M.2078 – Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced

–	Report ITU-R M.2079 – Technical and operational information for identifying spectrum for the terrestrial component of future development of IMT-2000 and IMT-Advanced

For more information please refer to: List of ITU-R Reports on IMT.

### B.1.3	ITU Handbooks

ITU-R and its Working Parties developed a number of ITU-R Handbooks as follows:

–	Handbook on Amateur and amateur-satellite services (www.itu.int/pub/R-HDB-52)

–	Handbook on Digital Radio-Relay Systems (www.itu.int/pub/R-HDB-24)

–	Handbook on Frequency adaptive communication systems and networks in the MF/HF bands (www.itu.int/pub/R-HDB-40)

–	Handbook on Land Mobile (including Wireless Access) Volume 1: Fixed Wireless Access (www.itu.int/pub/R-HDB-25)

–	Handbook on Land Mobile (including Wireless Access) Volume 2: Principles and Approaches on Evolution to IMT-2000/FPLMTS (www.itu.int/pub/R-HDB-30)

–	Handbook on Land Mobile (including Wireless Access) – Volume 3: Dispatch and Advanced Messaging Systems (www.itu.int/pub/R-HDB-47)

–	Handbook on Land Mobile (including Wireless Access) – Volume 4: Intelligent Transport Systems (www.itu.int/pub/R-HDB-49)

–	Handbook on Land Mobile (including Wireless Access) – Volume 5: Deployment of Broadband Wireless Access Systems (www.itu.int/pub/R-HDB-57)

–	Handbook on Migration to IMT-2000 Systems – Supplement 1 (Revision 1) of the Handbook on Deployment of IMT-2000 Systems (www.itu.int/pub/R-HDB-46)

–	Handbook on IMT-2000: Special Edition on CD-ROM (www.itu.int/pub/R-HDB- 37)

### B.2	External publications

### B.2.1	UMTS Forum Reports

–	UMTS Forum Report 1, "A Regulatory Framework for UMTS", 1997

–	UMTS Forum Report 2, "The Path towards UMTS – Technologies for the Information Society", 1998

–	UMTS Forum Report 4, "Considerations of Licensing Conditions for UMTS Network Operations", 1998

–	UMTS Forum Report 5, "Minimum Spectrum Demand per Public Terrestrial UMTS Operator in the Initial Phase", 1998

–	UMTS Forum Report 6, UMTS/IMT-2000 Spectrum, 1998

–	UMTS Forum Report 31, UMTS Next Generation Devices, January 2004

–	UMTS Forum Report 33, 3G Offered Traffic Characteristics, November 2003

–   UMTS Forum Report 35, Mobile Market Evolution and Forecast: Long term sociological, social and economical trends, June 2004

–   UMTS Forum Report 36, Benefits of Mobile Communications for the Society, June 2004

–   UMTS Forum Report 37, "Magic Mobile Future 2010-2020", April 2005

–   UMTS Forum Report 38, "Coverage Extension Bands for UMTS/IMT-2000 in the bands between 470-600 MHz", January 2005

–   UMTS Forum Report 39, "The Global Market for High Speed Packet Access (HSPA): Quantitative and Qualitative analysis", March 2006

–   UMTS Forum Report 40, "Development of spectrum requirement forecasts for IMT-2000 and systems beyond IMT-2000 (IMT-Advanced)", January 2006

–   UMTS Forum Report 41, "Market Potential for 3G LTE", July 2007

–   UMTS Forum Report 42, "LTE Mobile Broadband Ecosystem: the Global Opportunity", June 2009

–   UMTS Forum Report 43, "Two Worlds Connected: Consumer Electronics Meets Mobile Broadband", January 2011

–   UMTS Forum Report 44, "Mobile Traffic Forecasts 2010-2020", May 2011

–   UMTS Forum White Paper "Spectrum for future development of IMT-2000 and IMT-Advanced", 2012

–   UMTS Forum Report 45, "Study of Spectrum allocations and usage in the range 3 400-4 200 MHz (C-band)", February 2014

B.2.2   GSMA publications

–   GSMA mobile policy handbook

–   GSMA mobile economy series

–   Understanding 5G: perspectives on future technological advancements in mobile, December 2014

–   Today, tomorrow, and the future – managing data demand in Asia Pacific, November 2014

–   Enabling mobile broadband: a toolkit, November 2014

–   Wireless backhaul spectrum policy recommendations and analysis, October 2014

–   The cost of spectrum auction distortions, October 2014

–   Data demand explained, July 2014

–   Will Wi-Fi relieve congestion on cellular networks?, May 2014

–   The GSMA spectrum primer series: introducing radio spectrum, March 2014

–   The GSMA spectrum primer series: the spectrum policy dictionary, March 2014

–   The impact of licensed shared access use of spectrum, February 2014

–   Coexistence of ISDB-T and LTE, November 2013

–   Valuing the use of spectrum in the EU, June 2013

–   Securing the digital dividend for mobile broadband, May 2013

–   Advancing 3GPP networks: optimisation and overload management techniques to support smartphones, June 2012

- Licensing to support the mobile broadband revolution, May 2012
- HSPA & LTE advancements, February 2012
- GSMA spectrum handbook: understanding the basics of spectrum policy for mobile telecommunications, December 2011
- Mobile broadband evolution: securing the future of mobile broadband for the GSM community, February 2011
- The momentum behind LTE worldwide, January 2011
- MIMO in HSPA: the real-world impact, November 2010
- The 2.6 GHz spectrum band: an opportunity for global mobile broadband, January 2010

ANNEX C

Applications and services

C.1 Location based application and services

Location based application and services helps in determining the geographical position of a mobile phone/device, and delivers the position to the application requesting this information. Location based systems can be broadly divided into: a) network based; b) handset based and c) hybrid.

a)   Network based: Network-based techniques utilize the service provider's network infrastructure to identify the location of the handset. The advantage of network-based techniques (from mobile operator's point of view) is that they can be implemented without specific support for LBS (Location Based Services) from handsets. The accuracy of network-based techniques is dependent on the inter site distance and number of neighbouring base station cells.

b)   Handset based: The handset based technique generally uses GPS. In this case location determination calculation is done by the handset, and thus location information is generally more precise.

c)   Hybrid positioning systems use a combination of network-based and handset-based technologies for location determination. One example would be Assisted GPS, which uses both GPS and network information to compute the location. Hybrid-based techniques give the best accuracy of the two but inherit the limitations and challenges of network-based and handset-based technologies.

C.1.1 Location accuracy techniques

The following are the location techniques:

–   Cell Id

–   Cell Id +TA/ Cell ID+RTT

–   Enhanced Cell ID (ECID)

–   RF Pattern Matching

–   U-TDOA (LMU) based

–   O-TDOA

–   A-GPS

–   Mix of one or more of above.

C.1.1.1 Cell ID

a)   In this positioning mechanism, the serving cell of the target UE is translated to a geographical shape. This is a quick but low accuracy positioning mechanism. For this the positioning entity needs to have a database of Computer-Generated Imagery (CGI) and the corresponding radio coverage.

b)   Where can be deployed: Cell ID can be implemented regardless of technology.

c)   Salient points:

     i)   Limited accuracy

     ii)   No additional major deployment in network

     iii)   Works in all network technologies (GSMWCDMA, LTE).

C.1.1.2 Cell Id +TA/ Cell ID+RTT

a)   The TA is based on the existing Timing Advance (TA) parameter. The TA value is known for the serving BTS. To obtain TA values in case the MS is in idle mode a special call, not noticed by the GSM subscriber (no ringing tone), is set up. The cell-ID of the serving cell and the TA which is received is then used to determine the approximate distance of the UE from the tower.

     The Round Trip Time (RTT) measures the distance between the WCDMA-handset and the base station, i.e. with a similar purpose as TA in GSM. Accuracy depends upon various factors such as inter site distance, accuracy of Cell site data bases and stability in RF characteristics of the network. Works with WCDMA network.

b)   Salient points:

     i)   Cell Id + TA/ Cell Id + RTT positioning method is merely an enhancement of the Cell Id.

     ii)   The TA parameter is an estimate of the distance (in increments of 550 M) from the mobile terminal to the base station.

     iii)   The RTT measures the distance between the WCDMA-handset and the base station, i.e. with a similar purpose as TA in GSM.

     iv)   Works in all network technologies.

C.1.1.3 E-CID {(Cell Id +TA)/(Cell ID+RTT) & NMR}

a)   Network Management Reports (NMR) like power measurement can also be used to enhance accuracy of RTT and CGI.

b)   Salient points:

     i)   Medium accuracy around 200 meters in urban areas depending upon inter site distance and number of neighbours.

     ii)   Works in all network technologies.

C.1.1.4 RF Pattern Printing (RFPM)

Radio Frequency Pattern Printing (RFPM) is a positioning method that uses the RF patterns observed in the region to determine UE location using the NMRs as main inputs. RFPM compares "fingerprint" data received from the handsets with the database of radio frequency strength of the same area. This will improve accuracy considerably. Accuracy depends upon various factors such as inter site distance, accuracy of Cell site data bases and stability in RF characteristics of the network. RFPM works with GSM and WCDMA networks.

a)   RF Profiling/Pattern Matching/Fingerprinting- The technology is capable of meeting the 100 m/300 m requirement for network-based solutions in many urban and some dense suburban settings. Accuracy in urban, suburban/rural areas may be achieved depending upon inter site distance and number of neighbours.

b)   Works in all network technologies.

c)   RF fingerprinting requirements:

     i)   The method requires periodic drive tests and collection of data over the required area. The samples are to be collected at different point of time in a day or adaption of RF patterns data for different RF characteristics in a day.

     ii)   Large number of samples with the required parameters to be taken.

iii)   The drive test for in building and hand held drive test for congested locations (which are non-drivable) should also be done and integrated with the drive test of outdoor to generate RF pattern data.

iv)   Incremental drive test or tuning of RF measurement pattern is required in case of change in antenna power, tilt or beam width or when a new base station is installed or any base station stops radiating, the topology changes due to change in Landscape, infrastructure development, terrain, etc.

C.1.1.5   Uplink time duration of arrival (UTDOA) – Location management unit (LMU)

a)   This is software and hardware based solution to be installed along with an existing BTS. It will require backend infrastructure to collect process and present the required information.

b)   The technology is capable of meeting the 100 m/300 m requirement for network-based solutions. Higher accuracy in urban, suburban/rural areas may be achieved depending upon inter site distance and number of neighbours.

c)   Will require additional O&M of LMU hardware.

d)   Works in GSM.

e)   LMU requirements:

i)   At least two neighbours are required.

ii)   For synchronization, GPS infrastructure (GPS antenna, cable) is required.

iii)   Signalling connectivity between LMU Server and LMUs (located at BTS) is required.

iv)   It is an active element which requires connectivity at BTS.

C.1.1.6   Observed time duration of arrival (O-TDOA)

a)   To be deployed for LTE.

b)   O-TDOA is a downlink trilateration technique that requires the User Equipment (UE) to detect at least two neighbour eNodeBs.

c)   The UE requires O-TDOA software support in order to process the signals from multiple eNodeBs and interact with the E-SMLC/SLP (Evolved Serving Mobile Location Centre / SUPL Location Platform) server.

C.1.1.7   A-GPS

GPS is a satellite based positioning technology. In this UE calculated its location and provides it to the network. A variant of GPS is A-GPS wherein network provides initial assistance data to the UE to reduce the location determination time. GPS based mechanism generally does not work as well indoors or in areas where clear sky is not visible.

a)   Salient points:

i)   Good accuracy in Sub-urban/ Rural/Remote. In strong signal conditions (e.g. rural environment with user in clear sky conditions), the accuracy can be better than 10 m. In some dense urban or indoors environments, accuracy may degrade to the 50-100 m range.

ii)   Only works for users with GPS on their handsets.

iii)   GPS enabling is user controlled.

C.1.2 Factors impacting location accuracy

In all location accuracy a method except A-GPS, the accuracy is dependent on inter site distance and number of neighbours of BTSs. Lower the inter site distance the accuracy shall be higher. Also higher the number of neighbours the accuracy shall be higher.

C.1.3 Required features and issues in supporting LBS

a)   Location nodes i.e. GMLC (Gateway Mobile Location Centre), SMLC (Serving Mobile Location Centre) and its associated interfaces are required.

b)   The following are the requirements in various network elements for LBS support:

   i)   BSC/RNC:

   – Lb/Iupc Interface on every BSC/RNC

   – Network features required in each BSC/RNC

   – Unique Point Code/GT/RNCID in all BSCs/RNCs across all PLMNs

   – BSC/RNC Reachability – STP (Signalling Transfer Point) or Direct?

   – Full CGI (Cell Global Identifier) Value (MCC+MNC+LAC+CI) to be provided by BSCs

   – Full CGI Value (MCC+MNC+LAC/RNCID+CID) to be provided by RNCs.

   – Extra Load on BSC/RNC for All Call CDR (Call-detail Record) Requirement.

   ii)   MSC/MME:

   – Lg/SLg & SLs Interface on every MSC/MME

   – Network features required in each MSC/MME.

   iii)   HLR/HSS:

   – Lh/SLh Interface on every HLR/HSS

   – Network features required in each HLR/HSS.

   iv)   BTS/Node B/E-Node B:

   – Intersite Distance Requirement. Accuracy shall increase with lesser inter-site distance and more number of neighbours for network based solutions.

c)   As the usage of location based services increases, it will have impact on different network elements and signalling etc. for which re-dimensioning of various network elements may be required.

ANNEX D

Description of Wireless Backhaul Systems

– Recommendation ITU-R F.746 – Radio-frequency arrangements for fixed service systems

– Recommendation ITU-R F.752 – Diversity techniques for point-to-point fixed wireless systems

– Recommendation ITU-R F.755 – Point-to-multipoint systems in the fixed service

– Recommendation ITU-R F.1093 – Effects of multipath propagation on the design and operation of line-of-sight digital fixed wireless systems

– Recommendation ITU-R F.1101 – Characteristics of digital fixed wireless systems below about 17 GHz

– Recommendation ITU-R F.1102 – Characteristics of fixed wireless systems operating in frequency bands above about 17 GHz

– Recommendation ITU-R F.1668 – Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections

– Recommendation ITU-R F.1703 – Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections

ANNEX E

Description of the IMT-2000 radio interfaces and systems
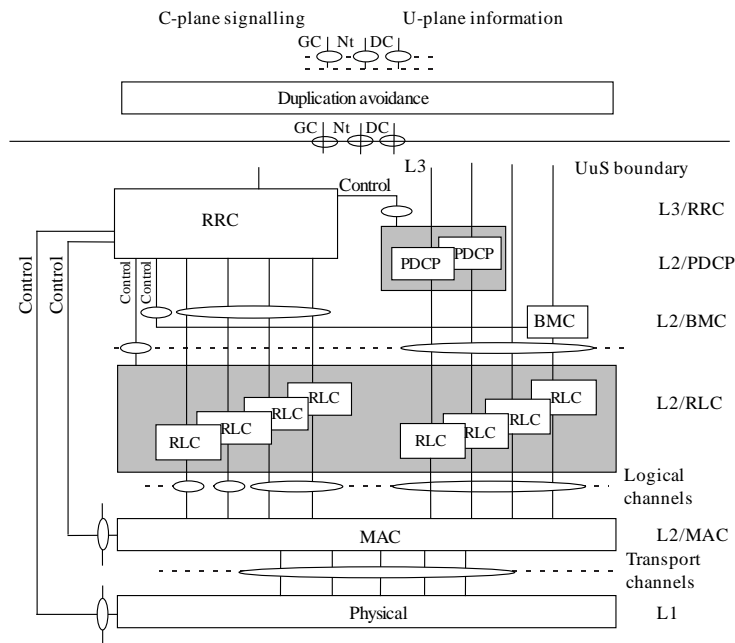
IMT-2000 CDMA Direct Spread

Figure 23 shows the radio interface protocol architecture for the radio access network. On a general level, the protocol architecture is similar to the current ITU-R protocol architecture as described in Recommendation ITU-R M.1035. Layer 2 (L2) is split into the following sub-layers; radio link control (RLC), medium access control (MAC), Packet Data Convergence Protocol (PDCP) and Broadcast/Multicast Control (BMC). Layer 3 (L3) and RLC are divided into control (C-plane) and user (U-plane) planes. In the C-plane, L3 is partitioned into sub-layers where the lowest sub-layer, denoted as radio resource control (RRC), interfaces with L2. The higher-layer signalling such as mobility management (MM) and call control (CC) are assumed to belong to the CN. There are no L3 elements in this radio interface for the U-plane.

Each block in Figure 23 represents an instance of the respective protocol. Service access points (SAPs) for peer-to-peer communication are marked with circles at the interface between sub-layers. The SAP between MAC and the physical layer provides the transport channels. A transport channel is characterized by how the information is transferred over the radio interface (see sections 5.1.1.3 "Physical layer" and 5.1.1.3.1 "Transport Channel" of Recommendation ITU-R M.1457 for an overview of the types of transport channels defined). The SAPs between RLC and the MAC sub-layer provide the logical channels. A logical channel is characterized by the type of information that is transferred over the radio interface. The logical channels are divided into control channels and traffic channels. The different types of logical channels are not further described in this overview. In the C-plane, the interface between RRC and higher L3 sub-layers (CC, MM) is defined by the general control (GC), notification (Nt) and dedicated control (DC) SAPs. These SAPs are not further discussed in this overview.

Also shown in Figure 23 are connections between RRC and MAC as well as RRC and L1 providing local inter-layer control services (including measurement results). An equivalent control interface exists between RRC and the RLC sub-layer. These interfaces allow the RRC to control the configuration of the lower layers. For this purpose separate control SAPs are defined between RRC and each lower layer (RLC, MAC, and L1).

FIGURE 23

Radio interface protocol architecture of the RRC sub layer (L2 and L1)

Global Trends-23

IMT-2000 CDMA TDD

The radio interface protocol architecture for IMT-2000 CDMA TDD is the same as CDMA Direct spread as shown in Figure 23.

IMT-2000 CDMA Multi-Carrier

As shown in Figure 24, this radio interface has a layered structure that provides a combination of voice, packet data, and circuit data services, according to the ISO/OSI reference model (i.e. Layer 1 – the physical layer, and Layer 2 – the link layer). Layer 2 is further subdivided into the link access control (LAC) sub-layer and the MAC sub-layer. Applications and upper layer protocols corresponding to OSI Layers 3 through 7 utilize the services provided by the LAC services, e.g. signalling services, voice services, data services (packet data and circuit data).

In this radio interface a generalized multimedia service model is supported. This allows any combination of voice, packet data, and circuit data services to be operated. The radio interface also includes a QoS control mechanism to balance the varying QoS requirements of multiple concurrent services (e.g. to support ISDN or RSVP network layer QoS capabilities).

FIGURE 24

General radio interface architecture
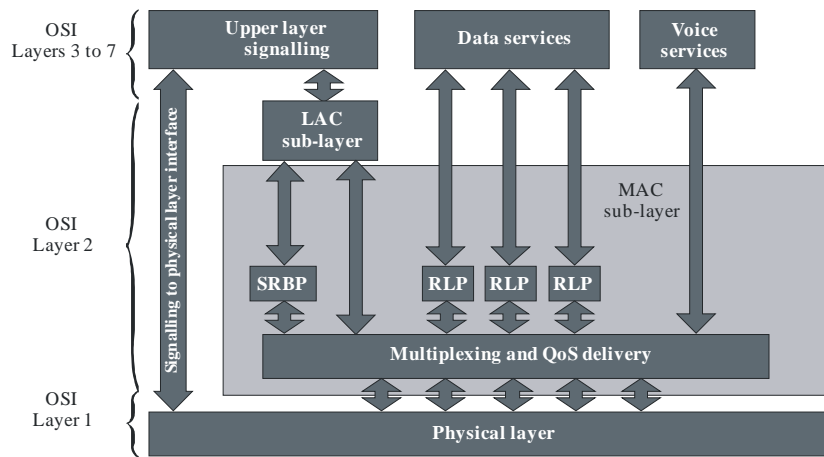
Global Trends-24

ANNEX F

Description of External Organizations

F.1   3GPP

The 3rd Generation Partnership Project (3GPP) unites six telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TTA, TTC), referred to as "Organizational Partners" and provides members with an independent and stable environment to produce the Reports and Specifications that specify and define 3GPP technologies. The work conducted within the 3GPP focuses on specific projects and studies aimed at the evolution and improvement of the standards that serve as the basis for the global cellular mobile industry.

The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities – including work on codecs, security and quality of service. It thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks.
3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level.

For more information please refer to http://www.3gpp.org/about-3gpp/about-3gpp

F.2   3GPP2

The Third Generation Partnership Project 2 (3GPP2) is a collaborative third generation telecommunications specifications-setting project comprising North American and Asian interests developing global specifications for ANSI/TIA/EIA-41 (MC_CDMA/cdma2000) Cellular Radio telecommunication Intersystem Operations network evolution to IMT-2000 and global specifications for the radio transmission technologies (RTTs) supported by ANSI/TIA/EIA-41.

3GPP2 was born out of the International Telecommunication Union's (ITU) International Mobile Telecommunications "IMT-2000" initiative.

F.3   IEEE

The IEEE Standards Association (IEEE-SA), a globally recognized standards-setting body within IEEE, develops consensus standards through an open process that engages industry and brings together a broad stakeholder community. IEEE standards set specifications and best practices based on current scientific and technological knowledge. The IEEE-SA has a portfolio of over 900 active standards and more than 500 standards under development.

The IEEE 802 LAN/MAN Standards Committee develops and maintains networking standards and recommended practices for local, metropolitan, and other area networks, using an open and accredited process, and advocates them on a global basis. The most widely used standards are for Ethernet, Bridging and Virtual Bridged LANs Wireless LAN, Wireless PAN, Wireless MAN, Wireless Coexistence, Media Independent Handover Services, and Wireless RAN. These standards are published by the IEEE Standards Association (IEEE-SA) of the Institute of Electrical and Electronics Engineers (IEEE). An individual Working Group provides the focus for each area.

The IEEE standards relevant for IMT-2000 OFDMA TDD WMAN, designated as IEEE Std 802.16 and IEEE Std 802.16.1, are developed and maintained by the IEEE 802.16 Working Group on Broadband Wireless Access.

ANNEX G

Published Recommendations, Reports and ongoing activities
of ITU-R on Terrestrial IMT

G.1 **Overall relationship diagram of ITU-R WP 5D deliverables and ongoing activities (since WP 5D #13)**

	IMT-2000 and IMT-Advanced	"IMT-2020"[61]
Application and service related aspects	–	– Rec. ITU-R M.[IMT.VISION]
	– Rep. ITU-R M.2117-1 – Rep. ITU-R M.2291-0 – Rep. ITU-R M.[IMT.AV]	
Technology related aspects	– Rec. ITU-R M.1457 – Recs. ITU-R M.1580-5, ITU-R M.1581-5 – Rec. ITU-R M.2012 – Recs. ITU-R M.2070, ITU-R M.2071 – Revision of Rec. ITU-R M.1579-1 – Rep. ITU-R M.[IMT.ARCH]	– Rep. ITU-R M.2320-0 – Rep. ITU-R M.[IMT.ABOVE 6 GHz]
Spectrum related aspect	– Rep. ITU-R M.2289-0 – Rec. ITU-R M.1768-1 – Rep. ITU-R M.2290-0 – Revision of Rec. ITU-R M.1036-4 – Rep. ITU-R M.[IMT.ARRANGEMENTS] – Rep. ITU-R M.2039-3 – Rep. ITU-R M.2292-0 – Rep. ITU-R M.[IMT.SMALL Cell] – Rep. ITU-R M.[TDD.COEXISTENCE]	– Rep. ITU-R M.[IMT.BEYOND2020 TRAFFIC]

G.2 **Published Recommendations and Reports of ITU-R related to Terrestrial IMT**

G.2.1 **Report ITU-R M.2117-1 – Software-defined radio in the land mobile, amateur and amateur-satellite services**

This Report addresses the application and implications of SDR to land mobile systems, including, but not limited to, IMT systems, dispatch systems, intelligent transport systems (ITS), public mobile systems including public protection and disaster relief (PPDR), first and second generation cellular systems including their enhancements, and amateur and amateur-satellite systems. It addresses issues on the characteristics, software download and its security, operational considerations such as spectrum usage and flexibility as well as certification and conformity, and SDR applications to specific land mobile systems.

The first revision of this Report was based on the recent results of ITU-R studies on SDR and CRS. The recent ITU-R study gives clear definitions to SDR and CRS. The contents on cognitive radio

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[61] The use of the term "IMT-2020" is a placeholder terminology and the specific nomenclature to be adopted for the future development of IMT is expected to be finalized at the Radiocommunication Assembly 2015.

system (CRS) and its related technologies were removed from this Report since the topics on CRS are elaborated and well-described in Report ITU-R M.2225. The term "IMT-2000 and systems beyond IMT-2000" was changed to general terminology of "IMT systems", taking into account the progress of the ITU-R study on IMT-2000 and IMT-Advanced. The SDR applications to ITS, PPDR as well as amateur and amateur-satellite systems were also updated according to the recent advance of the related technologies.

G.2.2 Recommendation ITU-R M.1457-11 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

This Recommendation has been developed based on consideration of the results of a defined evaluation process employed by the ITU-R on IMT-2000 radio proposals that have been submitted in response to a set of defined requirements. Further consideration was given to consensus building, recognizing the need to minimize the number of different radio interfaces and maximize their commonality keeping in mind the end-user needs, while incorporating the best possible performance capabilities in the various IMT-2000 radio operating environments.

The Radiocommunication Assembly recommends that the radio interfaces given in below should be those of the terrestrial component of IMT-2000.

– IMT-2000 CDMA Direct Spread
– IMT-2000 CDMA Multi-Carrier
– IMT-2000 CDMA TDD
– IMT-2000 TDMA Single-Carrier
– IMT-2000 FDMA/TDMA
– IMT-2000 OFDMA TDD WMAN.

Revisions to this Recommendation have been developed jointly by the ITU and the radio interface technology proponent organizations, global partnership projects and standards development organizations. Updates, enhancements and additions to the radio interfaces incorporated in this Recommendation have undergone a defined process of development and review to ensure consistency with the original goals and objectives established for IMT-2000 while acknowledging the obligation to accommodate the changing requirements of the global marketplace.

The main changes of the eleventh revision of Recommendation ITU-R M.1457 include the addition of enhanced capabilities for some of the radio interfaces, and some consequential changes to the overview sections of the text, as well as to the Global Core Specifications. Also the transposition references have been updated. In addition, section 6 ("Recommendations on unwanted emission limits") and Annex 1 ("Abbreviations") were reinserted (they were inadvertently omitted in the previous version of the Recommendation). Also a footnote was added in the Introduction in order to clarify the relation between Recommendation ITU-R M.1457 and Recommendation ITU-R M.2012. Further, a clarifying sentence on the specifications was added at the beginning of each section 5.x.2.

G.2.3 Recommendation ITU-R M.1457-12 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)

This 12th revision of Recommendation ITU-R M.1457 is intended to keep the specified technologies of the terrestrial component of IMT-2000 up to date. The main changes include the addition of enhanced capabilities for some of the radio interfaces, and some consequential changes to the overview sections of the text, as well as to the Global Core Specifications. Also the transposition references have been updated.

G.2.4 Recommendation ITU-R M.1768-1 – Methodology for calculation of spectrum requirements for the terrestrial component of International Mobile Telecommunications

This Recommendation presents the methodology for calculating the spectrum requirements for the further development of IMT. The methodology accommodates a complex mixture of services from market studies with service categories having different traffic volumes and QoS constraints. The methodology takes into account the time-varying and regionally-varying nature of traffic. The methodology applies a technology neutral approach to handle emerging as well as established systems using the Radio access technique group (RATG) approach with a limited set of radio parameters. The four RATGs considered cover all relevant radio access technologies.

RATG1: Pre-IMT systems, IMT-2000 and its enhancements.

RATG2: IMT-Advanced systems as described in Recommendation ITU-R M.2012.

RATG3: Existing radio LANs and their enhancements.

RATG4: Digital mobile broadcasting systems and their enhancements.

The methodology distributes traffic to different RATGs and radio environments using technical and market related information. For RATG3 and RATG4, no spectrum requirements are calculated. For the traffic distributed to RATG1 and RATG2, the methodology transforms the traffic volumes from market studies into capacity requirements using separate algorithms for packet-switched and circuit switched (reservation based) service categories and takes into account the gain in multiplexing packet services with different QoS characteristics. The methodology transforms capacity requirements into spectrum requirements using spectral efficiency values. The methodology considers practical network deployments to adjust the spectrum requirements and calculates the aggregate spectrum requirements for further development of IMT.

The first revision of this Recommendation includes two changes to the methodology itself and several editorial updates. The changes in the methodology are the following:

−   introduction of the granularity concept of spectrum deployment per operator per radio environment for improved increments;

−   due to the enhancement of network deployment in IMT-Advanced, the spectrum sharing approach between different radio environments in IMT-Advanced (RATG2) is changed to allow macro cells and micro cells to use the same frequencies. This change may impact the spectrum efficiencies which have to be taken into account in the input parameter values.

G.2.5 "User guide for the IMT spectrum requirement estimation tool" in ITU-R WP 5D Web page

The tool for the implementation of the methodology to determine global spectrum requirements for IMT in Recommendation ITU-R M.1768-1 is presented. This methodology and tool could also be used to estimate the total IMT spectrum requirements of a specific country if all the input parameter values are specified (as described in the methodology itself).

G.2.6 Report ITU-R M.2289-0 – Future radio aspect parameters for use with the terrestrial IMT spectrum estimate methodology of Recommendation ITU-R M.1768-1

This Report presents the future radio aspect parameters for use with the terrestrial IMT spectrum estimate methodology of Recommendation ITU-R M.1768-1 in conjunction with developing the

future spectrum requirement estimate for terrestrial IMT systems, principally focused towards the years 2020 and beyond.

G.2.7 Report ITU-R M.2292-0 – Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses

IMT systems have been the main method of delivering wide area mobile broadband applications. In order to accommodate increasing amount of mobile traffic and user demand for higher data rates, IMT-Advanced which is evolution of IMT-2000, is planned to be deployed in the world.

Frequency sharing studies and interference analyses involving IMT systems and other systems and services operating in the same or the adjacent bands may need to be undertaken within ITU-R. To perform the necessary sharing studies between IMT systems and systems in other services, characteristics of the terrestrial component of IMT-Advanced systems are needed.

This Report provides the baseline characteristics of terrestrial IMT-Advanced systems for use of sharing and compatibility studies between IMT-Advanced systems and other systems and services.

G.2.8 Report ITU-R M.2291-0 – The use of International Mobile Telecommunications for broadband public protection and disaster relief applications

This Report has considered how the use of IMT, and LTE in particular, can support current and possible future PPDR applications. The broadband PPDR communication applications are detailed in various ITU-R Resolutions, Recommendations and Reports; and this Report has assessed the LTE system capabilities to support these applications. This Report has also considered the benefits that can be realized when common radio interfaces technical features, and functional capabilities, are employed to address communications needs of public safety agencies. Also, the report describes the features and benefits that make LTE particularly suitable for PPDR applications as compared to traditional PPDR systems.

G.2.9 Report ITU-R M.2290-0 – Future spectrum requirements estimate for terrestrial IMT

This Report provides results of studies on estimated spectrum requirements for terrestrial IMT. The estimated spectrum requirements are calculated using the methodology defined in Recommendation ITU-R M.1768-1 and the corresponding input parameter values, taking into account recent advances in technologies and the deployments of terrestrial IMT networks as well as recent developments in mobile telecommunication markets.

The total spectrum requirements for both RATG 1 (i.e. pre-IMT, IMT-2000, and its enhancements) and RATG2 (i.e. IMT-Advanced) in the year 2020 are estimated using the two different settings in order to reflect differences in the markets and deployments and timings of the mobile data growth in different countries. The estimated total spectrum requirements for both the RATGs 1 and 2 are 1 340 MHz and 1 960 MHz for lower user density settings and higher user density settings, respectively.

G.2.10 Recommendation ITU-R M.2012-1 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)

This Recommendation identifies the terrestrial radio interface technologies of International Mobile Telecommunications-Advanced (IMT-Advanced) and provides the detailed radio interface specifications of "LTE-Advanced" and "WirelessMAN-Advanced". These radio interface specifications detail the features and parameters of IMT-Advanced. The 1st revision of Recommendation ITU-R M.2012 is intended to keep the specified technologies of the terrestrial

component of IMT-Advanced up to date. The main changes include the addition of enhanced capabilities for both radio interface technologies in Annexes, and some consequential changes to the overview sections of the text, as well as to the Global Core Specifications. Also the transposition references have been updated.

In addition, a footnote was added in the Introduction in order to clarify the relation between Recommendations ITU-R M.1457 and ITU-R M.2012 and also noting b) is added to refer to the evaluation results on revised RIT/SRIT.

G.2.11 Recommendation ITU-R M.1579-2 – Global circulation of IMT terrestrial terminals

The purpose of this Recommendation is to establish the technical basis for global circulation of IMT terrestrial terminals based on terminals not causing harmful interference in any country where they circulate:

– by conforming to IMT-2000 and IMT-Advanced terrestrial radio interface specifications; and

– by complying with unwanted emission limits for IMT-2000 and IMT-Advanced terrestrial radio interfaces.

This revision of Recommendation ITU-R M.1579-1 adds the technical basis for global circulation of IMT Advanced terminals.

G.2.12 Recommendation ITU-R M.1580-5 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000, and Recommendation ITU-R M.1581-5 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000

Recommendation ITU-R M.1580-5 provides the generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000. And, Recommendation M.1581-5 provides the generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT 2000, suitable for establishing the technical basis for global circulation of IMT-2000 terminals. Implementation of characteristics of base/mobile stations using the terrestrial radio interfaces of IMT-2000 in any of the bands included in this Recommendation is subject to compliance with the Radio Regulations.

G.2.13 Recommendation ITU-R M.2070 – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced, and Recommendation ITU-R M.2071 – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-Advanced

Recommendation ITU-R M.2070 provides the generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced. And, Recommendation ITU-R M.2071 provides the generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-Advanced, suitable for establishing the technical basis for global circulation of IMT-Advanced terminals. Implementation of characteristics of base/mobile stations using the terrestrial radio interfaces of IMT-Advanced in any of the bands included in this Recommendation is subject to compliance with the Radio Regulations.

G.2.14   Report ITU-R M.2039-3 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses

This Report provides the baseline characteristics of terrestrial IMT-2000 systems only for use in frequency sharing and interference analysis studies involving IMT-2000 systems and between IMT-2000 systems and other systems.

Recommendations ITU-R M.1457, ITU-R M.1580 and ITU-R M.1581 provide standardization information relating to IMT-2000 interfaces.

Parameters for IMT-Advanced interfaces are not addressed in this Report. They are addressed in Report ITU-R M.2292.

The characteristics of the IMT-2000 interfaces have been grouped by frequency ranges:

–   below 1 GHz,

–   between 1 and 3 GHz,

–   between 3 and 6 GHz.

Band specific variations, if any, are reflected in the tables.

G.2.15   Report ITU-R M.2320 – Future technology trends of terrestrial IMT systems

This Report provides a broad view of future technical aspects of terrestrial IMT systems considering the time frame 2015-2020 and beyond. It includes information on technical and operational characteristics of IMT systems, including the evolution of IMT through advances in technology and spectrally-efficient techniques, and their deployment.

Technologies described in this Report are collections of possible technology enablers which may be applied in the future. This Report does not preclude the adoption of any other technologies that exist or appear in the future, and newly emerging technologies are expected in the future.

G.2.16   Report ITU-R M.2334 – Passive and active antenna systems for base stations of IMT systems

This report addresses several aspects of active and passive antenna systems for base stations of IMT systems, including the definitions of antenna systems, associated components and terminology; definitions for common performance parameters and tolerances; guidelines on performance parameters and tolerances; and considerations of advanced concepts.

G.2.17   Recommendation ITU-R M.2083 – IMT Vision –"Framework and overall objectives of the future development of IMT for 2020 and beyond"

This Recommendation defines the framework and overall objectives of the future development of IMT for 2020 and beyond in light of the roles that IMT could play to better serve the needs of the networked society in the future. The framework of the future development of IMT for 2020 and beyond are described in detail in this Recommendation. This framework is defined considering the development of IMT systems to date based on the framework and overall objectives described in Recommendation ITU-R M.1645. This Recommendation addresses the framework and objectives of the future development of IMT for 2020 and beyond that fulfil the needs of future service scenarios and use cases for both the evolutionary path of existing IMT as well as for new IMT system capabilities.

G.2.18   Report ITU-R M.2376 – Technical feasibility of IMT in the bands above 6 GHz

This Report is to study and provide information on technical feasibility of IMT in the bands above 6 GHz. Technical feasibility includes information on how current IMT systems, their evolution, and/or potentially new IMT radio interface technologies and system approaches could be

appropriate for operation in the bands above 6 GHz, taking into account the impact of the propagation characteristics related to the possible future operation of IMT in those bands. Technology enablers such as developments in active and passive components, antenna techniques, deployment architectures, and the results of simulations and performance tests are considered.

G.2.19 Report ITU-R M.2370 – IMT Traffic estimates for the years 2020 to 2030

This Report includes estimates of IMT (including cellular and Mobile broadband) traffic and estimates of numbers of subscriptions and also including other relevant information impacting traffic estimation. This Report covers a period of 2020-2025 and even beyond.

G.2.20 Report ITU-R M.2374 – Coexistence of two TDD networks in the 2 300-2 400 MHz band

The band 2 300-2 400 MHz was globally identified for IMT at WRC-07 in accordance with Footnote **5.384A** in the Radio Regulations. The band 2 300-2 400 MHz is being used or is planned to be used for mobile broadband wireless access (BWA) including IMT technologies in a number of countries. This draft new Report will address on the coexistence of two co-located adjacent spectrum blocks in the 2 300-2 400 MHz band in TDD mode in order to maximize benefits from a harmonized use of the band.

G.2.21 Report ITU-R M.2375 – Architecture and topology of IMT networks

This Report provides an overview of the architecture and topology of IMT networks and a perspective on the dimensioning of the respective transport requirements in these topologies. This document covers different architectural aspects in a general level of detail.

G.2.22 Report ITU-R M.2373 –Audio-visual capabilities and applications supported by terrestrial IMT systems

This Report describes technical and operational characteristics of interactive unicast and multicast audio-visual services and applications provided over terrestrial IMT systems (AV over IMT), taking into consideration the evolving needs and user demands, trends and new user behaviours, and the particular needs, role and functions in developing economies.

G.2.23 Draft new Report ITU-R M.[IMT.ARRANGEMENTS] – Channelling arrangements for IMT adapted to the frequency band below 790 MHz down to around 694 MHz for Region 1

This draft new Report provides the harmonized channelling arrangements for IMT adapted to the frequency band below 790 MHz down to around 694 MHz for Region 1, as indicated in Resolution **232 (WRC-12)** "*invites ITU-R* 2", which directly supports WRC-15 agenda item 1.2, taking into account the existing arrangements in Region 1 in the bands between 790 and 862 MHz as defined in the last version of Recommendation ITU-R M.1036, in order to ensure coexistence with the networks operated in the new allocation and the operational networks in the band 790-862 MHz.

G.2.23 Report ITU-R M.2410 – Minimum requirements related to technical performance for IMT-2020 radio interface(s)

This Report describes key requirements related to the minimum technical performance of IMT-2020 candidate radio interface technologies. It also provides the necessary background information about the individual requirements and the justification for the items and values chosen. Provision of such background information is needed for a broader understanding of the requirements. This Report is based on the ongoing development activities of external research and technology organizations.

G.2.24   Report ITU-R M.2411 – Requirements, evaluation criteria and submission templates for the development of IMT-2020

This Report deals with on the requirements, evaluation criteria and submission templates for the development of Recommendations and Reports on IMT-2020, such as the detailed specifications of IMT 2020. It provides the service, spectrum and technical performance requirements for candidate Radio Interface Technologies (RITs)/Set of Radio Interface Technologies (SRITs) for IMT 2020.

G.2.25   Report ITU-R M.2412 – Guidelines for evaluation of radio interface technologies for IMT-2020

This Report provides guidelines for the procedure, the methodology and the criteria (technical, spectrum and service) to be used in evaluating the candidate IMT-2020 radio interface technologies (RITs) or Set of RITs (SRITs) for a number of test environments. These test environments are chosen to simulate closely the more stringent radio operating environments. The evaluation procedure is designed in such a way that the overall performance of the candidate RITs/SRITs may be fairly and equally assessed on a technical basis. It ensures that the overall IMT 2020 objectives are met.

G.2.26   Report ITU-R M.2440 – The use of the terrestrial component of International Mobile Telecommunications (IMT) for Narrowband and Broadband Machine-Type Communications

This Report addresses the technical and operational aspects of terrestrial IMT-based radio networks and systems supporting MTC applications, as well as spectrum needed, including possible harmonized use of spectrum to support the implementation of narrowband and broadband MTC infrastructure and devices.

G.2.27   Report ITU-R M.2441 – Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)

This Report is a compilation document on existing and new usage of International Mobile Telecommunication (IMT) in specific applications. Further, it introduces potential new emerging applications of IMT in areas beyond traditional voice, data and entertainment type communications. It is provided as a reference document on these important uses of IMT, as envisaged in the vision for IMT-2020.

G.2.28   Report ITU-R M.2483 – The outcome of the evaluation, consensus building and decision of the IMT-2020 process (Steps 4 to 7), including characteristics of IMT-2020 radio interfaces

This Report is the record of the work performed after receipt of the [complete] proposals for IMT-2020 candidate RITs and SRITs, including the evaluation activity and the consensus building. This text contains the outcome and conclusions of Steps 4-7 of the IMT-2020 process.

For a complete up-to-date list of published Recommendations, Reports and Handbooks on the terrestrial component of IMT, refer to the Guide to the use of the ITU-R texts relating to the terrestrial component of IMT:

https://www.itu.int/oth/R0A060000AA/en

G.3   Work ongoing and underway in ITU-R WP 5D

G.3.1   Draft 6th revision of Recommendation ITU-R M.1036 – Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands

This draft 6th revision of Recommendation provides guidance on the selection of transmitting and receiving frequency arrangements for the terrestrial component of IMT systems as well as the arrangements themselves, with a view to assisting administrations on spectrum-related technical issues relevant to the implementation and use of the terrestrial component of IMT in the bands identified in the RR. The frequency arrangements are recommended from the point of view of enabling the most effective and efficient use of the spectrum to deliver IMT services – while minimizing the impact on other systems or services in these bands – and facilitating the growth of IMT systems.

G.3.2   Draft 6th revision of Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of international mobile telecommunications-advanced (IMT-Advanced)

This draft 2nd revision of Recommendation ITU-R M.2012 is to include the latest technology updates to current IMT-Advanced RIT and SRIT based on the proposals from GCS Proponents, and to add new RIT/SRIT if new candidates are proposed, evaluated and agreed to be included as per current process.

G.3.3   Draft revision of Recommendation ITU-R M.2150 – Detailed specifications of the terrestrial radio interfaces of international mobile telecommunications-2020 (IMT-2020)

This draft revision of Recommendation ITU-R M.2150 is to include the latest technology updates to current IMT-2020 RIT and SRIT based on the proposals from GCS Proponents, and to add new RIT/SRIT if new candidates are proposed, evaluated and agreed to be included as per current process.

G.3.4   Draft new Recommendation ITU-R M.[IMT.VISION 2030 AND BEYOND] –IMT Vision – "Framework and overall objectives of the future development of IMT for 2030 and beyond"

The draft Recommendation will will focus on, but not to limited, what will be the roles of IMT and how could IMT better serve society in the future; and   defining the framework and overall objectives of IMT towards 2030 and beyond to drive the future developments for IMT including the radio access network which will also consider the framework for future development described in the Recommendation ITU-R M.2083.

G.3.5   Draft new Report ITU-R M.[IMT.ABOVE 100 GHz] –The technical feasibility of IMT in bands above 100 GHz

This draft Report is to study and provide information on technical feasibility of IMT in bands above 100 GHz complementing the studies carried in Report ITU-R M-2376. This technical feasibility Report includes information on propagation environment and channel models, as well as newly developed technology enablers such as active and passive components, antenna techniques, deployment architectures, and the results of simulations and performance tests.

G.3.6 Draft new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS]

This draft Report provides a broad view of future technical aspects of terrestrial IMT systems considering the time frame 2020-[2023] and beyond. It includes information on technical and operational characteristics of terrestrial IMT systems, including the evolution of IMT through advances in technology and spectrally-efficient techniques, and their deployment. Elements of this Report could be seen as useful for WRC-23 studies.

G.3.7 Draft new Report ITU-R M.[IMT TERRESTRIAL BROADBAND REMOTE COVERAGE] –Terrestrial IMT for remote sparsely populated areas providing high data rate coverage

This draft Report provides details on prospects associated with provisioning of enhanced terrestrial mobile broadband services to remote sparsely populated and under-served areas proposing enhancements of user equipment as well as for networks in suitable frequency bands

G.3.8 Draft new Report ITU-R M.[IMT-2020.TDD.SYNCHRONIZATION]

This draft Report addresses the study on the aspects of synchronization operations of multiple IMT-2020 TDD networks in close proximity using the same frequency band, including analyses of coexistence issues when IMT operators utilize different synchronization modes, performance evaluation under different synchronization modes, and coexistence mitigation strategies.

G.3.9 Draft new Report ITU-R M.[IMT.C-V2X] –Application of the Terrestrial Component of IMT for Cellular-V2X

Based on Question ITU-R 262/5, this Report will address the mutual relationship between IMT technologies and required functions of one specific application, Cellular-Vehicle-to-Everything (C-V2X), for the various scenarios. The Report will further provide details of capabilities, technical demands and operational characteristics associated with C-V2X using terrestrial component of IMT systems.

G.3.10 Draft new Report ITU-R M.[IMT.INDUSTRY] - APPLICATIONS OF IMT FOR [SPECIFIC] INDUSTRIAL AND ENTERPRISE USAGES

[Editor Note]: Gernel description on the draft ITU-R Reprot will be further developed

G.3.11 Draft new Report ITU-R M.UUUU –The outcome of 'Way Forward Option 2' of the evaluation, consensus building and decision of the IMT-2020 process (Steps 4 to 7), including characteristics of IMT-2020 radio interfaces

The draft Report will be the record of the work performed after receipt of complete proposals for IMT-2020 candidate RITs and SRITs, including evaluation activity and consensus building for IMT-2020/17(Rev.1) and IMT-2020/18(Rev.1) according to IMT-2020/52 (the agreed way forward Option 2), IMT-2020/53 and IMT-2020/54 in Option 2 re-evaluation process. This text contains outcome and conclusions of rewind Steps 4-7 of the IMT-2020 process.

G.3.12 Draft new Report ITU-R M.AAS –Advanced antenna system (AAS) pattern for sharing studies between IMT-2020 systems and other services

ITU-R WP 5D is developing a Report on the advanced antenna system (AAS) pattern model for use in sharing and compatibility studies between IMT-2020 systems and systems in other services. The initial focus of the work is on the adjacent frequency-band antenna pattern.

G.3.13 Draft new Report ITU-R M.[XXX] –Technical measures to ensure coexistence between the MSS in the frequency band 1 518-1 525 MHz and IMT in the frequency band 1 492-1 518 MHz

The studies will focus on the technical coexistence conditions between IMT in the frequency band 1 492-1 518 MHz and Mobile Satellite Service in the band 1 518-1 525 MHz.

G.3.14 Draft new Recommendation ITU-R M.[FSS_ES_IMT_26GHz] – Methods to assist administrations to mitigate interference from FSS earth stations into IMT stations operating in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz

ITU-R WP 5D is developing an ITU-R Recommendation to assist administrations to mitigate interference from FSS earth stations into IMT stations operating in the frequency bands 24.65-25.25 GHz and 27-27.5 GHz

G.3.15 Draft new Report/Recommendation ITU-R M.[FSS_ES_IMT_40GHz] – *[Editoral Note]: the Title will be further developed*

ITU-R WP 5D is developing a ITU-R Reports and Recommendations, as appropriate, to assist administrations in ensuring coexistence between IMT and BSS, FSS, including HDFSS as per RR No. **5.516B** within the frequency range 37-43.5 GHz and 47.2-48.2 GHz as appropriate, taking into account the *invites administrations* of Resolution **243 (WRC-19)**

G.3.16 Draft new Report ITU-R M.[HIBS-CHARACTERISTICS] – Spectrum needs, usage and deployment scenarios, and technical and operational characteristics for the use of high-altitude platform stations as IMT base stations (HIBS) in the mobile service in certain frequency bands below 2.7 GHz already identified for IMT

Ongoing activities of ITU-R WP 5D planned to be finalized in June 2023 (WP 5D #22):

–   XXXX

[Editor's Note: Since the ongoing activities of WP 5D are updated at every meeting of WP 5D, the Handbook drafting group considered whether a single reference to the latest WP 5D chairman's report would be sufficient here in Section G.3]

For the latest ongoing activities of ITU-R WP 5D refer to the latest Chairman's Report:

https://www.itu.int/ITU-R/go/rwp5d/

G.4   All list of ITU-R Recommendations and Reports on IMT

For a complete up-to-date list of published Recommendations, Reports and Handbooks on the terrestrial component of IMT, refer to the Guide to the use of the ITU-R texts relating to the terrestrial component of IMT:

https://www.itu.int/oth/R0A060000AA/en

ANNEX H

Satellite IMT (and other, related) Recommendations and Reports

[Editor's Note: The BR is kindly requested to update this list]

– Recommendation ITU-R M.1850-2 – Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)

– Report ITU-R M.2176-1 – Vision and requirements for the satellite radio interface(s) of IMT-Advanced

– Report ITU-R M.2279 – Outcome of the evaluation, consensus building and decision of the IMT-Advanced satellite process (Steps 4 to 7), including characteristics of IMT Advanced satellite radio interfaces

– Recommendation ITU-R M.2047 – Detailed specifications of the satellite radio interfaces of International Mobile Telecommunications-Advanced (IMT-Advanced)

– Recommendation ITU-R M.687-2 – International Mobile Telecommunications-2000 (IMT-2000)

– Recommendation ITU-R M.818-2 – Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)

– Recommendation ITU-R M.1167 – Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)

– Recommendation ITU-R M.1391-1 – Methodology for the calculation of IMT-2000 satellite spectrum requirements

– Report ITU-R M.2041-0 – Sharing and adjacent band compatibility in the 2.5 GHz band between the terrestrial and satellite components of IMT-2000

– Report ITU-R M.2077-0 – Traffic forecasts and estimated spectrum requirements for the satellite component of IMT-2000 and systems beyond IMT-2000 for the period 2010 to 2020

ANNEX I

Technology migration in a given frequency band

[Editor's note: This Annex needs to be revised.]

I.1   Frequency resource allocation

Two frequency allocation modes are available, depending on the operator's spectrum resource usage: edge frequency allocation and sandwich frequency allocation. These schemes are depicted in Figure 25.

FIGURE 25

Multi-RAT frequency allocations
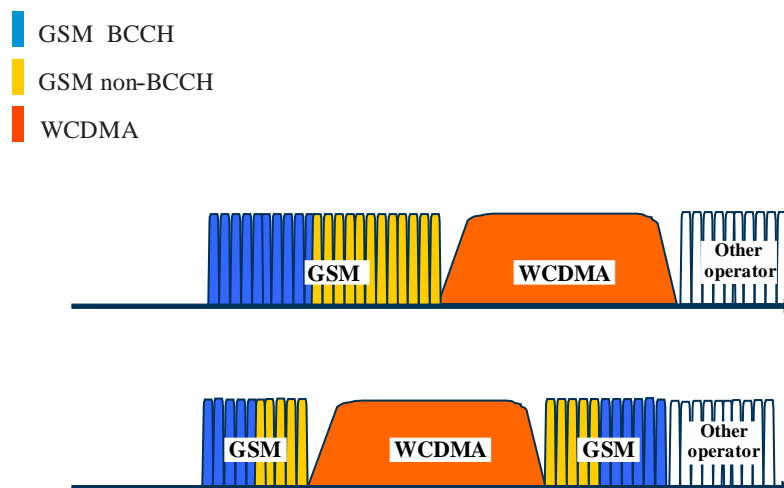
Global Trends-25

Edge Frequency Allocation

The UMTS/LTE and GSM systems are arranged side-by-side and maintain standard central frequency separation from the UMTS/LTE and GSM of other operators.

Sandwich Frequency Allocation

Within the frequency band of an operator, the UMTS/LTE is arranged in the middle with the GSM on both sides. If the operator has abundant frequency resources, it may allocate a second UMTS carrier or bigger bandwidth LTE as network services expand. At this point, the UMTS/LTE can be arranged at one side of the operator's frequency band for asymmetric sandwich allocation. The GSM spectrum at the other side is as wide as possible, and thus the UMTS/LTE planned does not require adjustment, which facilitates smooth capacity expansion.

For the single sided method, only one additional guard band is needed while in the sandwich allocation two additional guard bands are needed. The sandwich allocation does not require the consideration of interference with the systems of other operators.

Non-standard frequency separation planning

Due to limited frequency resources and high GSM capacity demand, non-standard frequency separation can be adopted to increase frequency efficiency.

In UMTS 900 MHz network, the bandwidth may be less than 5 MHz because of smaller frequency resource from GSM network. Thus, non-standard frequency separation is adopted. And UMTS 4.2 MHz is the recommended solution for both UMTS network deployment feasibility and the benefit to GSM. Besides, UMTS 4.6 MHz, 3.8 MHz also is possible to be adopted. In Figure 26, when using UMTS non-standard bandwidth 4.6 MHz, 4.2 MHz, 3.8 MHz; 2, 4, 6 frequency channels can be saved for GSM correspondingly.

It is possible to operate WCDMA with a carrier as low as 4.2 MHz. However, it should be noted that even though a bandwidth less than 5 MHZ is not standardized for MS or RBS (Radio Base Station), it only implies minimal loss of capacity for WCDMA.

The sandwich allocation method is the preferred solution if 4.2 MHz is allocated for WCDMA. In that case it is preferable to use WCDMA carrier centred in own spectrum to avoid un-coordinated scenarios with other operators.

FIGURE 26

UMTS non-standard separation configuration
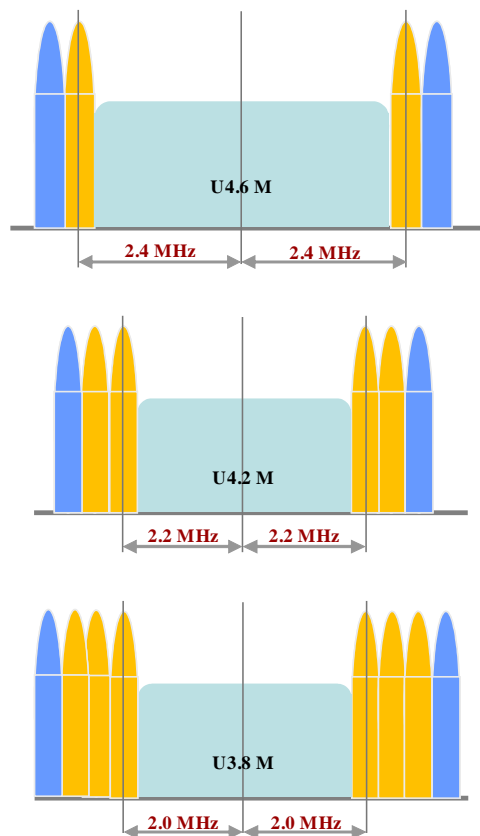
Global Trends-26

For 1 800 MHz bands which preferable re-farming direction is LTE, a similar issue exists. If 1 800 MHz frequency resource owned by one operator is insufficient, Compact Bandwidth can be enabled so that the LTE1800 network can be deployed by re-farming from GSM networks.

GSM frequency resources are substantially reduced after re-farming. GSM traffic will not fall in the short term, however, and in some areas may even increase slightly. This may result in capacity issues of GSM system. This issue may be addressed through traffic migration and tight frequency reuse.

Buffer zone solution

In the case of GSM and UMTS/LTE co-channel interference, a space separation is required to reduce the co-channel interference as illustrated in Figure 27 below. Areas with UMTS/LTE networks deployed and their peripheral areas form a band-type area. In this area, GSM networks cannot use frequencies overlapped in UMTS/LTE frequency spectrums and therefore GSM network capacity decreases. A large space separation for co-channel interference decreases impacts of GSM and UMTS/LTE co-channel interference on network performance. For space separation for co-channel interference, buffer zone planning solution is based on emulation and onsite traffic statistics to accommodate different scenarios.

FIGURE 27

Buffer Zone Solution

Global Trends-27
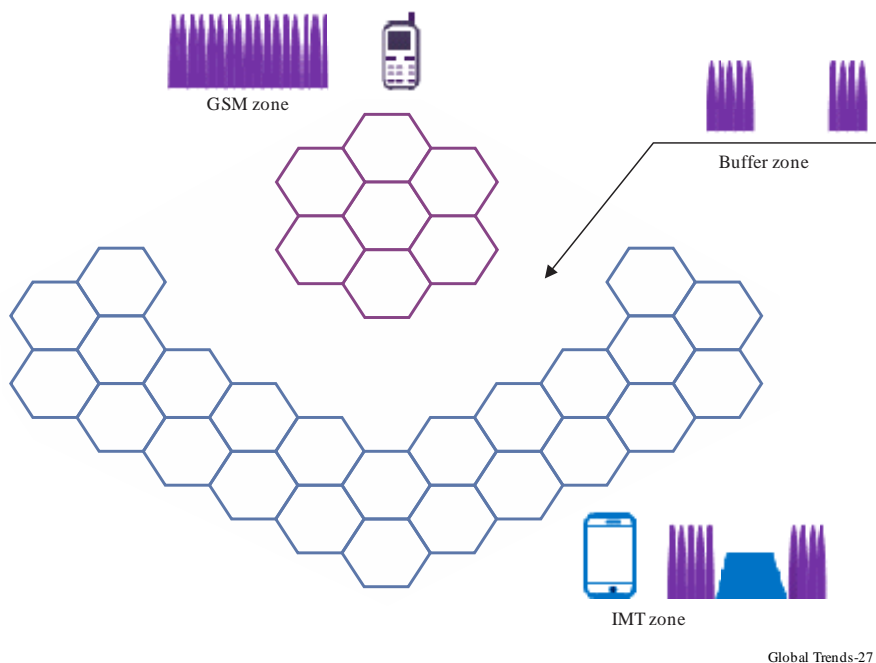
I.2   Coexistence between GSM and IMT in the adjacent frequencies

I.2.1   Interference and intermodulation issues

Interference

When GSM re-farming is implemented, except for interference between GSM and UMTS/LTE under standard separation or non-standard separation, narrow band interference in UMTS/LTE network is stricter. The narrow band interference may be from GSM TRXs that are not cleared completely, or may be from external interference source, like traffic light, broadcast signal, etc. These interference signals are not constant, and their strength is variable.

Intermodulation

Intermodulation problems can occur after GSM re-farming, when GSM will coexist with UMTS or LTE in one band. The intermodulation may be caused by antenna aging, feeder/jumper connection loose, etc., which will also exist in all other RAT combinations as well (as well as single RAT GSM operation).

Guard Band and Carrier Separation

The definition of guard band and carrier separation used in this document is shown in Figure 28 below:

FIGURE 28

Carrier separation and guard band

Global Trends-28
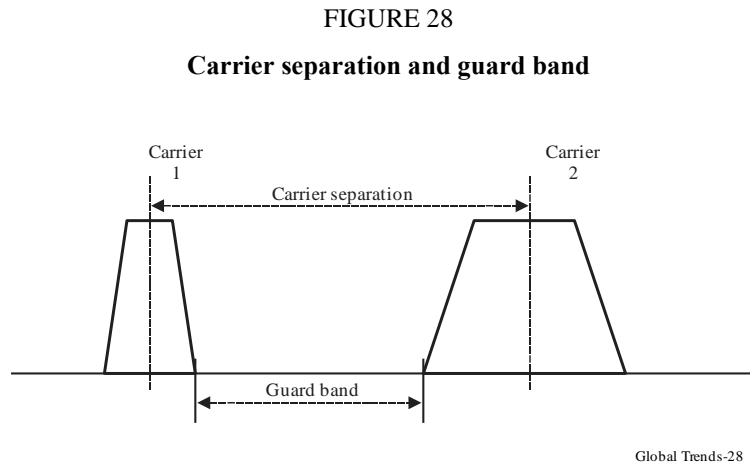
Carrier separation: the frequency band between two carrier centres.

Guard band: the unutilized frequency band between two carriers.

I.2.2   Coexistence between GSM and WCDMA

An example of Sharing/Coexistence between GSM and WCDMA in the adjacent frequencies is presented in Figure 29. Given an operator that will deploy WCDMA within its current limited GSM spectrum the issues can be summarized as:

–   Re-farming of many GSM carriers makes the GSM frequency re-planning "difficult" but creates "few" inter-system interference issues (case a) below).

–   Re-farming of few GSM carriers makes the GSM frequency re-planning "easy" but creates "severe" inter-system interference issues (case b) below).

FIGURE 29

Two Re-farming scenarios

a) larger bandwidth for WCDMA - fewer GSM carriers

b) Smaller bandwidth for WCDMA - more GSM carriers
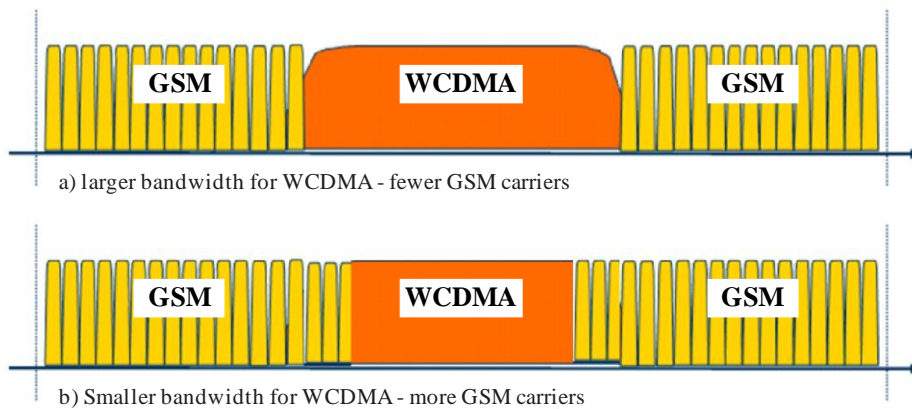
Global Trends-29

I.2.2.1 Interference and site scenarios

Due to the imperfectness of the transmitter and/or receiver we may list some interference scenarios on how GSM and WCDMA interfere with each other.

FIGURE 30

What and where the potential problems are

Two site scenarios:

. Coordinated, all WCDMA and GSM RBSs are located at the same geographical location

. Un-coordinated, no site sharing. WCDMA and GSM RBSs on different geographical locations.

Two ways of 'placing' a WCDMA carrier:

Four cases:
1. GSM RBS interfering WCDMA UE.
2. WCDMA RBS interfering GSM MS.
3. GSM MS interfering WCDMA RBS.
4. WCDMA UE interfering GSM RBS.
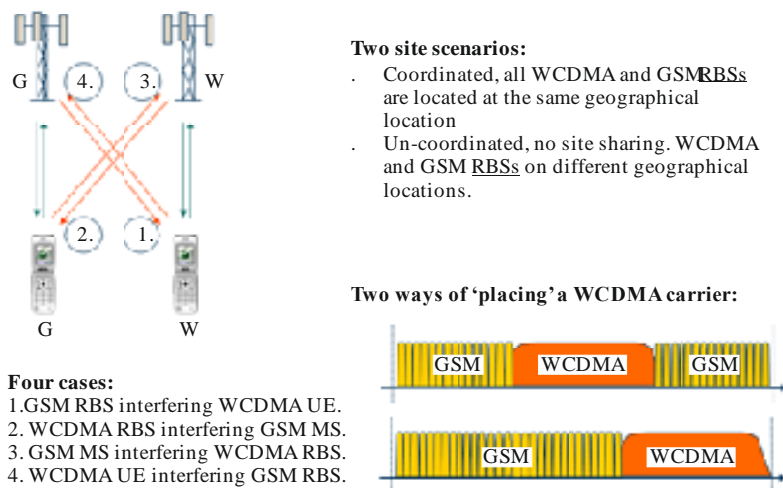
Global Trends-30

As Figure 30 is illustrating, there are four important interference cases

– GSM downlink interfering with the WCDMA downlink

– WCDMA downlink interfering with the GSM downlink

– GSM uplink interfering with the WCDMA uplink

– WCDMA uplink interfering with the GSM uplink.

In addition there are two site scenarios to consider:

– Coordinated sites, i.e. the WCDMA and GSM antennas are co-located

–   Un-coordinated sites, i.e. there is no site sharing.

I.2.2.2   WCDMA Downlink capacity loss due to GSM

The WCDMA DL (Downlink) capacity loss is controlled by the WCDMA terminal channel selectivity requiring at least a 2.8 MHz separation.

It is therefore difficult to make a prediction about performance if the carrier separation is decreased. However, regardless of the terminal performance, at a channel separation of 2.2-2.3 MHz the channel leakage increases dramatically and would make it very difficult indeed to operate with this kind of channel separation.

However, if the GSM channel power is sufficiently controlled and the traffic load is small it is possible to operate at a tolerable impact on the DL capacity.

One way of achieving this is to make sure that the GSM channels that overlap the WCDMA carrier (have spacing smaller than 2.6 MHz) are used in a low traffic sub-cell layer and aggressive BTS power control is used (and hence the impact on the DL WCDMA capacity also minimized).

I.2.2.3   WCDMA Uplink capacity loss due to GSM

The WCDMA UL (Uplink) capacity loss is assumed to be controlled by the GSM terminal channel leakage. The GSM channel leakage behaves acceptable until 2.2-2.3 MHz carrier spacing, below which it becomes very difficult to operate.

Note that GSM terminals have a limited dynamic range for power control and at some small path loss they simply do not down regulate anymore. This implies that a single GSM terminal can cause severe WCDMA UL noise rise and corresponding severe degradation in coverage.

The remedy here is to make sure that the load on overlapping carriers (any carrier with a channel separation to the WCDMA carrier lower then say 2.4 MHz) must be very low indeed.

Another remedy is to avoid using these GSM carriers close to the base station.

I.2.2.4   GSM Uplink capacity loss due to WCDMA

The GSM UL performance is controlled by the WCDMA terminal channel leakage which is insignificant for a 2.8 MHz carrier separation.

From the specification data the critical point comes below 2.5-2.6 MHz separation where the channel leakage suddenly increases.

The GSM UL performance should degrade at channel separation below 2.5 MHz, however given that WCDMA terminals have a much larger dynamic range in their power control it is a much less impacting effect than the one expected in WCDMA UL loss and the GSM UL performance on channels overlapping the WCDMA carrier is not significantly affected.

I.2.2.5   GSM Downlink capacity loss due to WCDMA

The GSM DL outage is insignificant for a 2.8 MHz carrier separation.

Assuming that the WCDMA base station controls the GSM DL performance at smaller channel separations a critical point appears to be at channel spacing around 2.5-2.6 MHz. Going below that seems to be very difficult.

I.2.2.6   Summary

The preferred scenario is to use coordinated GSM and WCDMA sites and the WCDMA carrier sandwiched in-between GSM carriers. The closest/overlapping GSM carriers should be TCH (Traffic Channel) only (not a BCCH-Broadcast Control Channel- carrier), having the smallest

traffic load possible and aggressive power control. This setup allows the use of a carrier spacing as low as 2.5 MHz with low performance degradation both on WCDMA and GSM.

I.3 Coexistence of Various GSM/CDMA-MC/UMTS/LTE Technologies in 850 and 900 MHz Bands

Although initially the 900 MHz band spectrum (UL: 880-915 MHz, DL: 925-960 MHz) was used for GSM technology, at present in many countries this band is also being used for UMTS and LTE technologies. Similarly, the 850 MHz band spectrum (UL: 824-849 MHz, DL: 869-894 MHz) is initially used for CDMA-MC technology and now it is also being used for UMTS and LTE technologies, as a replacement. Because of the closeness between the 850 MHz band downlink spectrum with the 900 MHz band uplink spectrum, there is higher possibility for inter-band interference issues. Also due to multiple technologies being used with the 850/900 MHz band spectrum, there is a possibility for intra-band interference issues happening within the 850/900 MHz band spectrum. While collocated/coordinated deployments solve most of the intra-band interference issues, the inter-band interference issues would exist in both collocated/non-collocated deployment scenarios. The inter-band interference issues between the 850 MHz band downlink and the 900 MHz band uplink at 880/890 MHz boundary are very severe in nature and needs special attention to solve those interference issues.

With CDMA, UMTS and LTE technologies being used in the 850 MHz band (assuming GSM850 possibility in Asia-Pacific region is very remote) and any of the GSM, UMTS and LTE technologies being used in the 900 MHz band (as shown in Figure 31), the following types of inter-band interference issues are observed between the 850 MHz band downlink and the 900 MHz band uplink at 880/890 MHz boundary:

– CDMA/UMTS/LTE850 base station transmission affecting the reception performance of GSM/UMTS/LTE900 base station (900 MHz band uplink is getting affected).

– GSM/UMTS/LTE900 mobile transmission affecting the reception performance of the CDMA/UMTS/LTE850 mobile (850 MHz band downlink is getting affected).

FIGURE 31

Inter-band interference issues between 850 and 900 MHz bands systems

I.3.1 **Inter-band and Intra-band Interference issues between 850 and 900 MHz Bands**

The inter-band interference issues are mainly either downlink-uplink or uplink-downlink type of interference issues and they are more severe in nature. This type of interference issues are difficult to deal with because they would generally lead to performance degradation if not tackled properly. There are two types of inter-band interference issues and they are:

–   Downlink Tx of the last 850 MHz band carrier (base station transmit) affecting the first 900 MHz band carrier's Uplink Rx (base station receive);

–   First 900 MHz band carrier's Uplink Tx (mobile transmit) affecting the last 850 MHz band carrier's Downlink Rx (mobile receive).

The two major interference issues with aggressors transmit affecting victim's receive are:

–   Out-of-band emissions (OOBE) of the aggressor signal entering as in-band interference that can degrade the uplink performance at the victim's receiver

–   High power adjacent channel signal of the aggressor acting as strong Adjacent Channel Interference (ACI) which may desensitize the victim's receiver

While the OOBE type of interference can only be minimized at the source (at the aggressor's transmitter) by improving the Adjacent Channel Leakage Ratio (ACLR) properties of the Aggressor through additional transmit filtering, the ACI type of interference can be minimized at the destination (at the victim's receiver) by having better Adjacent Channel Selectivity (ACS) properties of the Victim through additional receive filtering. To get the required additional ACLR/ACS characteristics, extra filtering is possible in the base stations. Whereas, for cost and space reasons it may not be possible to have such additional filters in mobiles.

Minimum Coupling Loss (MCL) based approach can be used to calculate the amount of isolation required to counter the effect of out-of-band emissions as well as the adjacent channel interference of the aggressor. The required isolation in base station to base station inter-band interference issues is achieved partly through spatial isolation from physical separation of antennas and remaining through special filters in Aggressor's transmit and Victim's receive paths.

In the inter-band interference issues case, there are two different problems, one with the 850 MHz band base station transmit signal affecting the performance of the 900 MHz band base station receive and the other with the 900 MHz band mobile transmit affecting the performance of the 850 MHz band mobile receive. In case of less than 90 dB of antenna isolation availability between the 850 MHz band base station and the 900 MHz band base station antennas, assuming always 10 to 15 dB (more than the standards required value) of additional ACLR and ACS would be available for base stations, then there is a need for additional 30+ dB of ACLR (through OOBE filtering) in the 850 MHz band base station Tx path as well as additional 20+ dB of ACS (through ACI filtering) in the 900 MHz band base stations' Rx path.

In the case of the 900 MHz band mobile Tx affecting the 850 MHz band mobile Rx, interference free operation is not possible as the additional ACLR/ACS requirement is high and also it is not possible (cost and space point-of-view) to have additional filters in mobiles. However, the probability of mobile to mobile interference happening is very low, because the conditions that two close by 900 MHz band and 850 MHz band mobiles simultaneously in active state and both in weak coverage state is very rare. Even though there is no additional filtering solution possible in mobiles (no mitigation solution available for the aggressor mobile Tx interference on victim mobile Rx), due to very low probability of such mobile-to-mobile interference happening (less than 2%), the victim downlink degradation possibility would also be very less.

Hence, to avoid inter-band interference issues, it is advisable (to the mobile wireless operators) to procure base station equipment along with such additional filtering in all UMTS850 and UMTS900

and LTE900 systems at the time of initial purchase itself. If not done during initial purchase, it is also possible to add these additional filters at a later stage.

As new IMT (e.g. UMTS, LTE) technologies gets introduced into the 900 MHz band spectrum as an overlay over the existing GSM technology deployments by carving out some spectrum, special care has to be taken by the operators on two fronts. One is choosing the right technology for the overlay and the other is the amount of spectrum to be carved out for the new technology. Also to be kept in mind is the knowhow on the possible intra-band interference issues and the ways and means to tackle such interference issues.

The intra-band interference issues can occur between two technologies operating in adjacent slots of the spectrum, especially when the base stations of these two technologies are deployed in an uncoordinated fashion. In the overlay with new technology scenario, it is going to be mostly a coordinated deployment and hence no intra-band interference issues. There is a slight advantage for UMTS900 overlay over the LTE900 overlay (in coordinated case), because of the additional guard band availability with a 5 MHz UMTS900 carrier, that allows two extra GSM (TCH) carriers in each side of the UMTS900 carrier (i.e. total of four GSM carriers), compared to no extra GSM carriers possible with a 5 MHz LTE900 carrier. In an un-coordinated (non-collocated) base station deployment (at the edge of operator's spectrum) case, for minimal intra-band interference; 5 MHz of spectrum is required to be carved out for a UMTS900 carrier and 5.2 MHz of spectrum is required to be carved out for an LTE900 carrier.

I.3.2 Guard Band requirement in Inter-band case for cost-effective filtering

Sufficient guard band (GB) between two inter-band systems is required to not only achieve the standards based ACLR and ACS values but also to have cost-effective filters in order to achieve additional isolation to fulfil the total isolation requirement for interference free operation. For cost effective filtering in base stations, nearly 1.6 to 2.0 MHz of guard band is required between the two inter-band adjacent carriers. Any additional GB is always good to have, as it would further help in getting increased isolation from filters at lesser cost, but it would lead to spectrum wastage. Table 2 shown below gives suggested edge-to-edge separation (guard band) in MHz between two adjacent aggressor and victim carriers. We assume, it is cost effectively possible to get the required additional ACLR (up to 50 dB) for OOBE isolation and the required additional ACS (up to 35 dB) for ACI isolation through special filters, with such amounts of GB provision.

TABLE 2

Suggested inter-band guard band between 850 and 900 MHz Bands carriers[62]

Technology in 850 MHz band	Technology in 900 MHz band	Suggested Edge-to-Edge Separation (Guard Band in MHz)
CDMA (1.23 MHz)	GSM (200 kHz)	1.6
CDMA (1.23 MHz)	UMTS (5 MHz)	1.6
CDMA (1.23 MHz)	LTE (5/10/15/20 MHz)	1.8/2.1/2.5/3.0
UMTS (5 MHz)	GSM (200 kHz)	1.6
UMTS (5 MHz)	UMTS (5 MHz)	1.6

_____

[62] This is based on the assumption of antenna isolation of 60 dB. For more detailed information please refer to reference [9].

UMTS (5 MHz)	LTE (5/10/15/20 MHz)	1.6/1.9/2.3/2.8
LTE (5/10/15/20 MHz)	GSM (200 kHz)	1.8/2.1/2.5/3.0
LTE (5/10/15/20 MHz)	UMTS (5 MHz)	1.6/1.9/2.3/2.8
LTE (5/10/15/20 MHz)	LTE (5/10/15/20 MHz)	1.8/2.1/2.5/3.0

I.4   Coexistence studies from CEPT between GSM and other systems

When the European Commission issued a mandate to CEPT on the technical conditions for allowing LTE and possibly other technologies within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands), it has been studied the technical conditions under which LTE technology (and other technology identified) can be deployed in the 900/1 800 MHz bands.

CEPT Report 40 ("in band") [6] summarized the compatibility study for LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands)

Based on the analysis of the simulation results of the interference between LTE/WiMAX and GSM, the frequency separation between the LTE/WiMAX channel edge and the nearest GSM carrier's channel edge is derived as follows:

–   When LTE/WiMAX networks in 900/1800 MHz band and GSM900/1800 networks are in uncoordinated operation, the recommended frequency separation between the LTE/WiMAX channel edge and the nearest GSM carrier's channel edge is 200 kHz or more.

–   When LTE/WiMAX networks in 900/1 800 MHz band and GSM900/1800 networks are in coordinated operation (co-located sites), no frequency separation is required between the LTE/WiMAX channel edge and the nearest GSM carrier's channel edge.

–   The recommended frequency separation of 200 kHz or more for the uncoordinated operation can be reduced based on agreement between network operators, bearing in mind that the LTE/WiMAX wideband system may suffer some interference from GSM due to LTE/WiMAX BS/UE receiver narrow band blocking effect.

CEPT Report 41 ("adjacent band") [7] summarized compatibility study between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands) and systems operating in adjacent bands

CEPT Report 42 [8] summarized the investigation on compatibility between UMTS and adjacent band systems above 960 MHz. The Report focuses on the compatibility between UMTS 900 on the one hand, and the aeronautical systems (existing: DME and future: L-DACS) in the band 960-1 215/1 164 MHz.

ANNEX J

References

[Editor's note: This Annex needs to be revised.]

[1]   3GPP TS 23.402 V12.7.0 (2014-12), Technical Specification Group Services and System Aspects; Architecture enhancements for non-3GPP accesses

[2]   3GPP TS 36.101 V12.6.0 (2014-12): "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception" (Table 5.5-1)

[3]   3GPP TS 25.101 V12.6.0 (2014-12): "Technical Specification Group Radio Access Network; User Equipment (UE) radio transmission and reception (FDD)" (Table 5.0)

[4]   3GPP TS 25.102 V12.0.0 (2014-09): "Technical Specification Group Radio Access Network; User Equipment (UE) radio transmission and reception (TDD)" (Section 5.2)

[5]   3GPP2 C.S0057-E Version 1.0 October 2010: "Band Class Specification for cdma2000 Spread Spectrum Systems Revision E

[6]   CEPT Report 40, Compatibility study for LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1 710-1 785 MHz / 1 805-1 880 MHz (900/1 800 MHz bands)

[7]   CEPT Report 41, Compatibility between LTE and WiMAX operating within the bands 880-915 MHz / 925-960 MHz and 1710-1785 MHz / 1805-1880 MHz (900/1800 MHz bands) and systems operating in adjacent bands

[8]   CEPT Report 42, Compatibility between UMTS and existing and planned aeronautical systems above 960 MHz

[9]   APT-AWG-REP-53 MIGRATION STRATEGY OF GSM TO MOBILE BROADBAND, September 2014

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