♦ Securing Spectrum Through the ITU to Fuel the Growth of Next-Generation Wireless Technologies

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Mobile data traffic is increasing exponentially and the ability of mobile broadband (MBB) technologies, such as Long Term Evolution-Advanced (LTE-A), to meet this demand depends on the availability of spectrum beyond that which is currently available to cellular mobile systems. This additional spectrum will be needed even considering the gains that will be delivered by LTE and LTE-A's higher spectral efficiency and the use of cell densification. Allocating and making spectrum available on a global basis is a complex process that is managed by the International Telecommunication Union (ITU) on a worldwide scale. Alcatel-Lucent and the wider mobile industry are working to harmonize this spectrum as much as possible to improve economies of scale for mobile broadband technologies and products. This paper describes the current "spectrum crunch," the spectrum allocation process, steps being taken to make more effective use of available spectrum, and the challenges in making additional spectrum available for the success of next-generation wireless networks. © 2013 Alcatel-Lucent.

Introduction

As has been well documented in the popular press, the market for cellular phones and other mobile broadband devices, such as tablets with mobile connectivity, is accelerating rapidly. As of December 2012, there were around six billion mobile subscriptions in a world population numbering almost seven billion individuals. Furthermore, the immense growth in cellular subscriptions over the last decade has been accompanied by the convergence of mobile with previously disparate sectors like the Internet and broadcasting. This has resulted in what some have called the *mobile data explosion* [6]. This extraordinary demand has placed pressure on the industry to respond with innovative technologies and approaches to network design. Mobile data traffic growth and some of the techniques to tackle it are addressed in the section on "The Mobile Data Explosion."

The best efforts of the engineers and the advances made in next-generation wireless technologies cannot, however, overcome the increasing scarcity in the availability of radio spectrum at suitable frequencies for mobile communication. The section on "The Spectrum Shortfall" provides elaboration on this topic.

The demand for additional spectrum is being addressed on a number of fronts: international, regional, and national. On a worldwide scale, spectrum allocation is managed by the International Telecommunication Union (ITU). Regional organizations, such as the

Bell Labs Technical Journal 18(2), 99–115 (2013) © 2013 Alcatel-Lucent. Published by Wiley Periodicals, Inc.
Published online in Wiley Online Library (wileyonlinelibrary.com) • DOI: 10.1002/bltj.21607

Panel 1. Abbreviations, Acronyms, and Terms

2G—Second generation
3G—Third generation
3GPP—3rd Generation Partnership Project
AI—Agenda item
APAC—Asia Pacific
APT—Asia-Pacific Telecommunity
ASMG—Arab Spectrum Management Group
ATU—African Telecommunications Union
CAGR—Compound annual growth rate
CDMA—Code Division Multiple Access
CEPT—European Conference of Postal and Telecommunications Administrations
CITEL—Inter-American Telecommunication Commission
CoMP—Coordinated multipoint
EDGE—Enhanced Data Rates for GSM Evolution
eICIC—Enhanced inter-cell interference coordination
EMEA—Europe, Middle East, and Africa
EU—European Union
FDD—Frequency division duplexing
GPRS—General Packet Radio Service
GSM—Global System for Mobile Communications
HSPA—High Speed Packet Access
HSPA+—Evolved High Speed Packet Access
ICT—Information and communication technology
IMT—International Mobile Telecommunications
IP—Internet Protocol
ITU—International Telecommunication Union
ITU-R—ITU Radiocommunication Sector
LTE—Long Term Evolution
LTE-A—LTE-Advanced
MBB—Mobile broadband
MIMO—Multiple input multiple output
NAR—North American Region
RCC—Regional Commonwealth in the field of Communication
RF—Radio frequency
RR—Radio Regulations
SG—Study Group
TDD—Time division duplexing
UMTS—Universal Mobile Telecommunications System
WiMAX—Worldwide Interoperability for Microwave Access
WP—Working Party
WRC—World Radiocommunication Conference

Asia-Pacific Telecommunity (APT), the Arab Spectrum Management Group (ASMG), the African Telecommunications Union (ATU), the European Conference of Postal and Telecommunications Administrations (CEPT), the Inter-American Telecommunication Commission (CITEL), and the Regional Commonwealth in the field of Communication (RCC) are developing regional approaches to spectrum usage. Finally, each nation has the sovereign right to determine the use of spectrum within its borders—dependent on certain ITU guidelines. To make spectrum available for operators, engagement is necessary on each of these fronts. This topic is outlined in "The International Spectrum Allocation Process" section.

As part of the effort to address the needs of our customers, Alcatel-Lucent is engaged on all fronts leading or participating in various working groups in ITU and the regional organizations (CEPT, APT, and CITEL). In particular, within the ITU, Alcatel-Lucent is engaged in preparatory work for the World Radiocommunication Conference 2015 (WRC-15) which will determine what additional spectrum, if any, will be made available for terrestrial mobile broadband, e.g., International Mobile Telecommunications (IMT), which is the ITU term for mobile broadband technologies such as Enhanced Data Rates for GSM Evolution (EDGE), General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA-2000), Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE and LTE-Advanced). The final section details the specific objectives Alcatel-Lucent and the mobile industry as a whole are pursuing to secure appropriate and sufficient spectrum to enable next-generation wireless technologies to succeed.

It is our hope that this overview of the problem, the methods to address it, and the actions being taken by Alcatel-Lucent and the mobile industry will aid understanding of the role international spectrum policy plays in enabling next-generation wireless deployment.

The Mobile Data Explosion

Mobile broadband (MBB) has made it possible for innovative services and applications to be developed "at the speed of ideas™". By "mobile broadband," we refer to mobile services using technologies that can offer third generation (3G) bit rates or higher (such as High Speed Packet Access (HSPA), Evolved HSPA (HSPA+) and LTE). Therefore, GSM and GPRS are not considered mobile broadband technologies. Mobile broadband is an enabling technology that can support many applications on the same, always-on, access line—from voice to data, from sound to video, from wireline to wireless, and from location-based to global communication services [6, 11].

The rapid uptake of smartphones, tablets, and innovative mobile broadband applications has resulted in an increase in the volume of mobile data traffic that was not taken into account in the 2007 traffic forecasts that were used to identify spectrum for IMT.

The main factors behind the mobile data explosion are:

- *Video.* A Bell Labs Traffic Index study completed in 2012 estimates that by 2016 video streaming and communications will account for almost 66 percent of all mobile traffic, as shown in **Figure 1**. This would represent a five-year compound annual growth rate (CAGR) of 95 percent [6].
- *Device proliferation.* In 2011, shipments of tablets reached 66.9 million with a one-year CAGR of 260 percent [18]. 2012 estimates indicated that 67 million LTE phones and 131 million tablets were sold. Market forecasts predict that approximately one in seven people will purchase a new smartphone in 2016 [20]. It is expected that in the 2013–2017 period the global shipments of tablets and other portable smart devices will

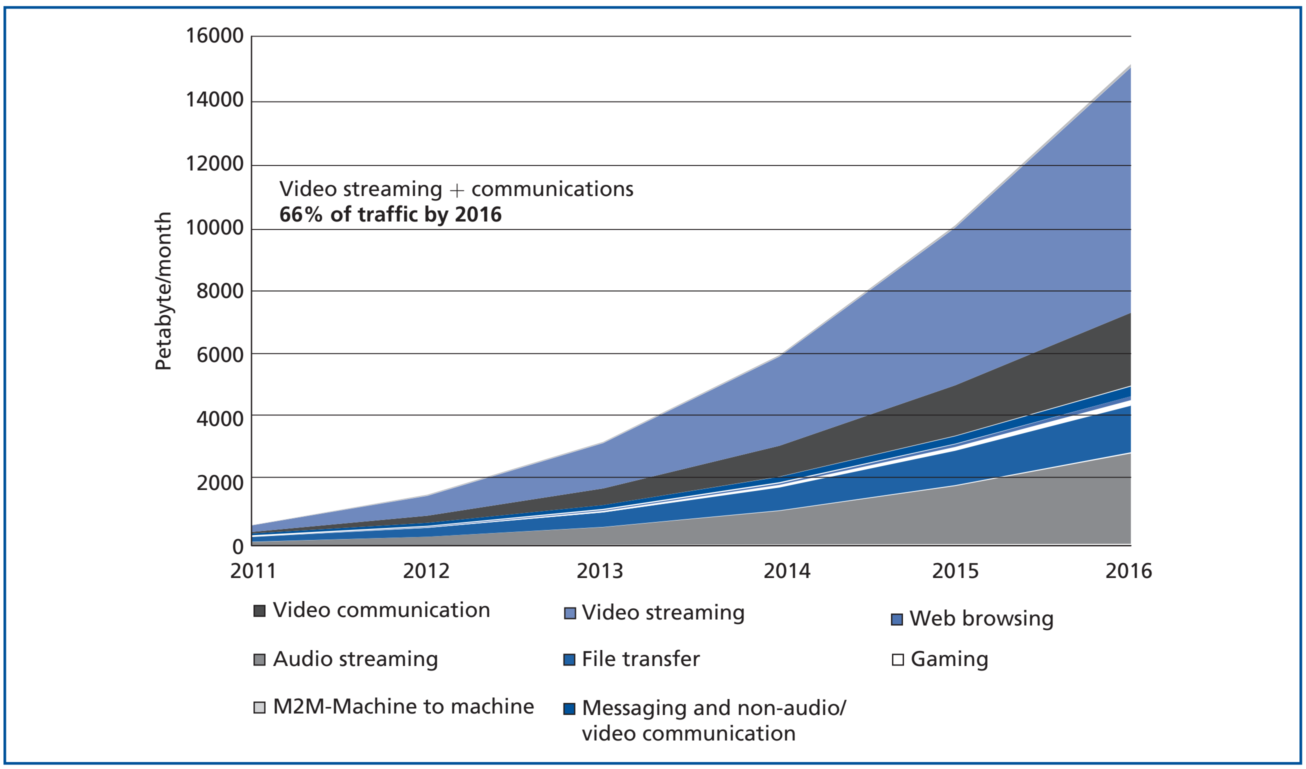

Figure 1.
Cumulative traffic distribution for Europe, North America, and Asia Pacific from 2011 to 2016.

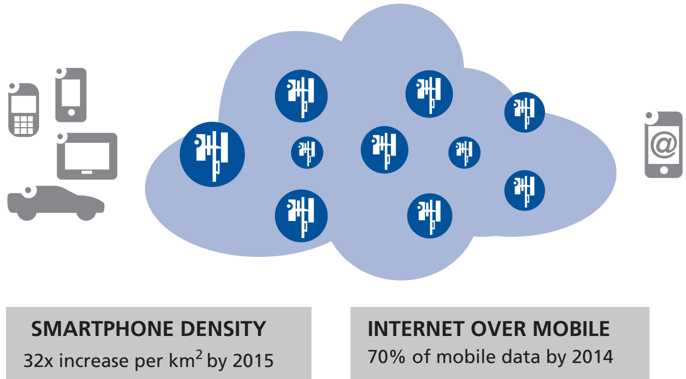

Figure 2.
Data drivers.

reach 1.4 billion units, making this the fastest-growing category of consumer electronics ever seen [17]. **Figure 2** reflects some figures concerning data drivers.

- *Application uptake*. The rate at which applications are being adopted is accelerating. Applications can go viral overnight. In 2010, iPhone users in the US downloaded 60 applications a year, three times the average for all mobile users [5].

The 2012 Bell Labs Traffic Index study took these factors into consideration and the resulting conclusion for the mobile data explosion is depicted in **Figure 3** for different regions of Europe/European Union (EU), the Asia Pacific (APAC), and the North American Region (NAR). Total mobile data traffic is estimated to be over 15 petabytes per month in 2016 (Wi-Fi offloaded traffic included), which represents a 25-fold growth rate over five years, with APAC exhibiting the most significant growth over the study period.

Operators are addressing the growth in mobile data demand through a range of methods, a few of which are outlined below.

Methods to Address the Increase in Data Traffic

Mobile network operators have at their disposal a number of approaches to address the increase in mobile data traffic. The most usual ones include:

- The adoption of more efficient technologies that assure a better spectral efficiency,
- The increase of capacity through network densification,
- Offloading traffic from the macro network, and
- The use of additional spectrum for mobile broadband.

These approaches are illustrated in **Figure 4**. Moving clockwise from the upper left, we examine each of these options in more detail:

- *Adopting more efficient mobile broadband technologies.* Operators are constantly driving spectral efficiency improvements and the use of technologies, such as IMT-Advanced, will certainly allow them to handle some of the increase in mobile data traffic. This drive toward greater spectral efficiency has pushed the continuous evolution of mobile broadband technologies, including the implementation of an all-Internet Protocol (IP) open Internet network architecture. Among the features of IMT-Advanced that will facilitate greater efficiency are multiple input multiple output (MIMO), coordinated multipoint (CoMP) transmission, and enhanced inter cell interference coordination (eICIC). **Figure 5** illustrates the evolution of 3rd Generation Partnership Project (3GPP) technologies over time (from GPRS to LTE), with their steady increases in spectral efficiency as measured in bits per second of aggregate throughput per Hz-occupied spectrum. Shannon's Law suggests that there is a physical limit to spectral efficiency, and gains will become increasingly difficult as the limit is approached [1, 2]. The spectral efficiency of LTE-A is not shown in Figure 5. However, Alcatel-Lucent's view (in

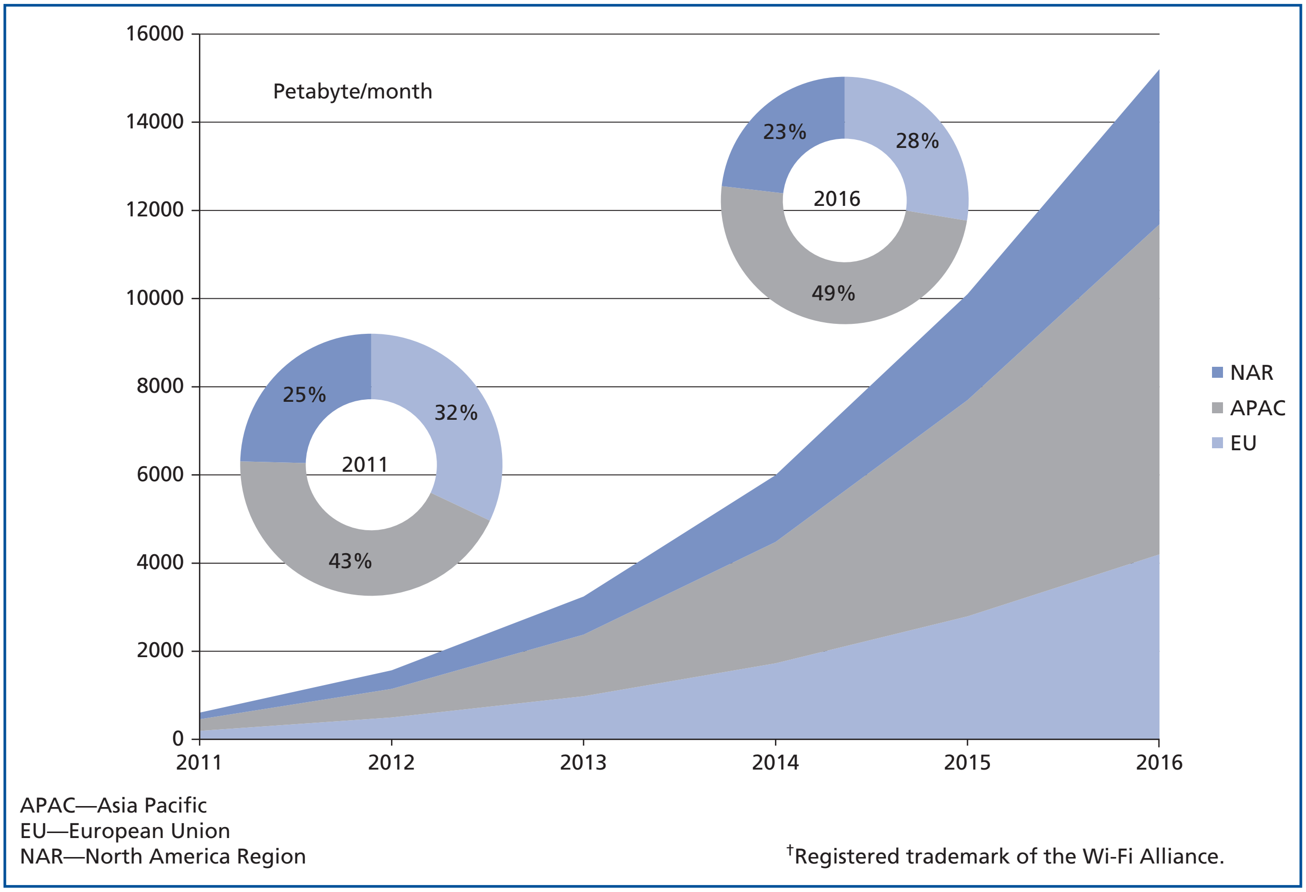

Figure 3.
Explosion of mobile data demand in different regions in terms of petabytes (10^9 megabytes). Wi-Fi† offloaded traffic included.

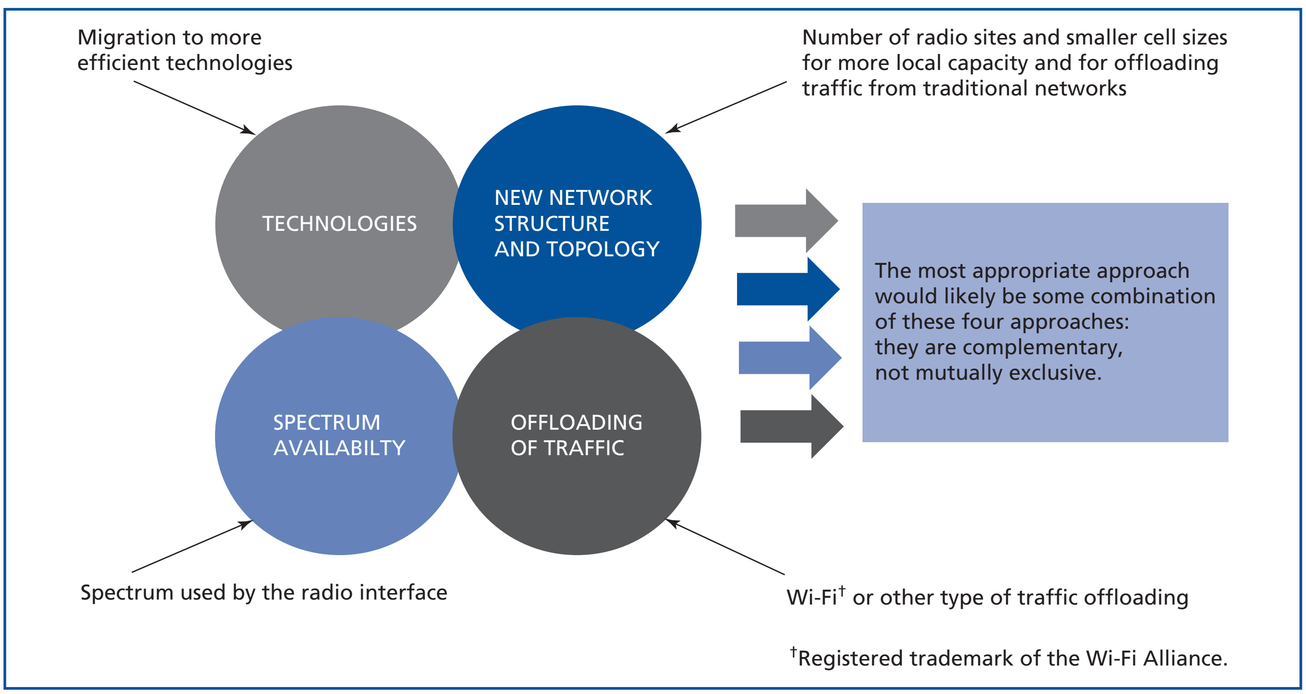

Figure 4.
Various approaches to meet the increasing mobile traffic demand.

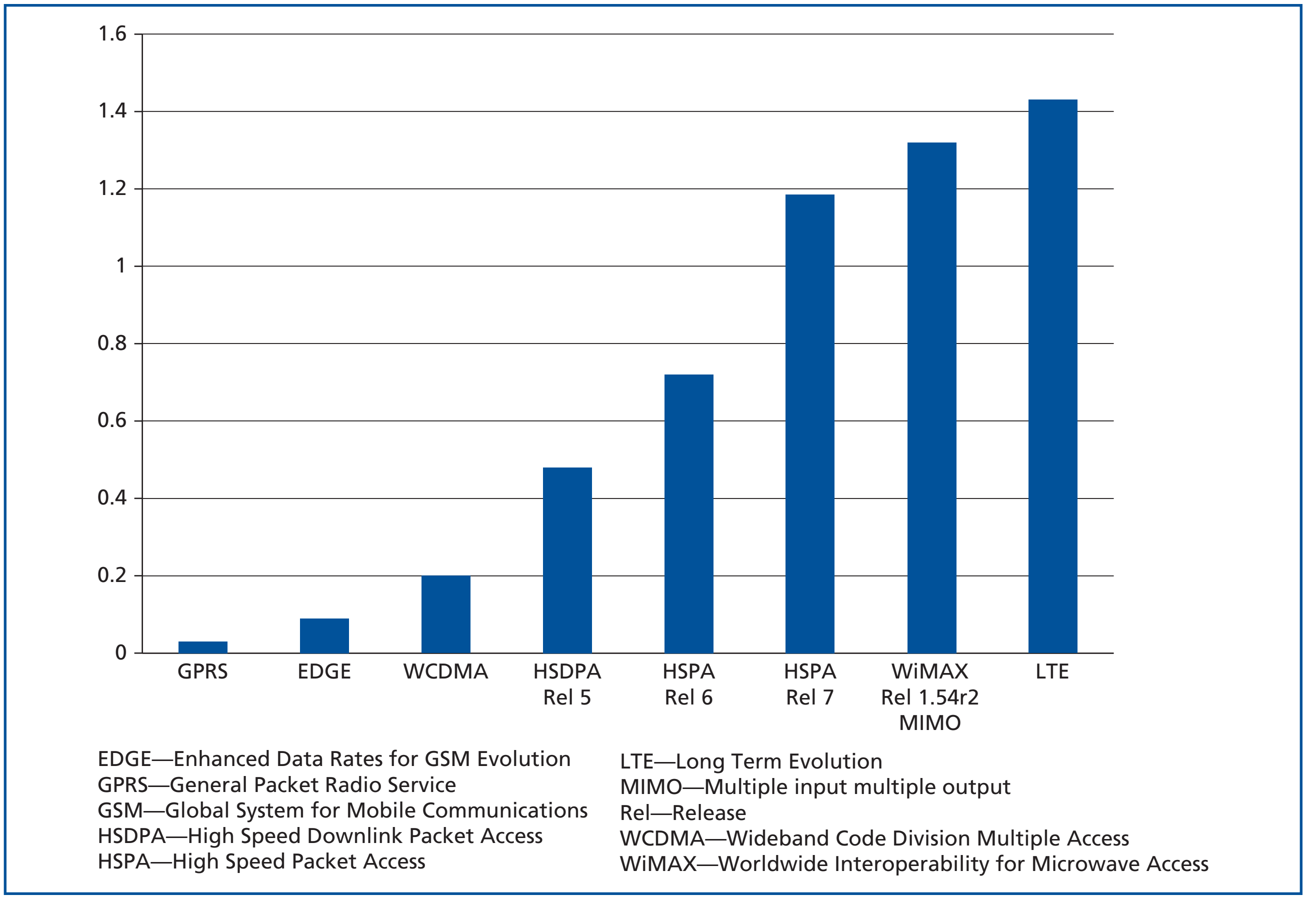

Figure 5.
Downlink spectral efficiency (in bits per second/Hz) by technology.

agreement with actual and simulated 3GPP figures) is that the downlink spectral efficiency of LTE-A can be considered as 2.4 bps/Hz.

The opening of spectrum currently used by 2G and 3G technologies (e.g., 900, 1800, and 2100 MHz bands) to new technologies (IMT-2000, IMT-Advanced) will allow more capacity to be delivered over existing IMT spectrum. To date, peak wireless spectral efficiency is doubling every 30 months [3], but user demand for bandwidth doubles at a much faster rate, every 11 months. In addition, improvements in radio link performance of advanced mobile broadband technologies are approaching their theoretical limit (i.e., the Shannon limit).

- *Improving capacity through network densification*, such as applying new network structure/topologies, can also relieve data traffic congestion, particularly in urban areas. Alcatel-Lucent's lightRadio™ and lightRadio™ Metro Cell Express solution are key enablers of network densification [6].

  As with spectral efficiency, network operators have taken a similar aggressive approach to densification of their networks. The trend toward more and more cells with diminishing cell radii is forecast to continue in the near future [1]. One estimate provided by Alcatel-Lucent is illustrated in **Figure 6**.
- *Offloading traffic* via Wi-Fi and small cells/femtocells can provide some relief as traffic is rerouted to landline networks.
- Finally, *increasing the amount and type of spectrum available* can help the operator handle the increased mobile data traffic.

It should be noted that the most appropriate approach to addressing the mobile data explosion

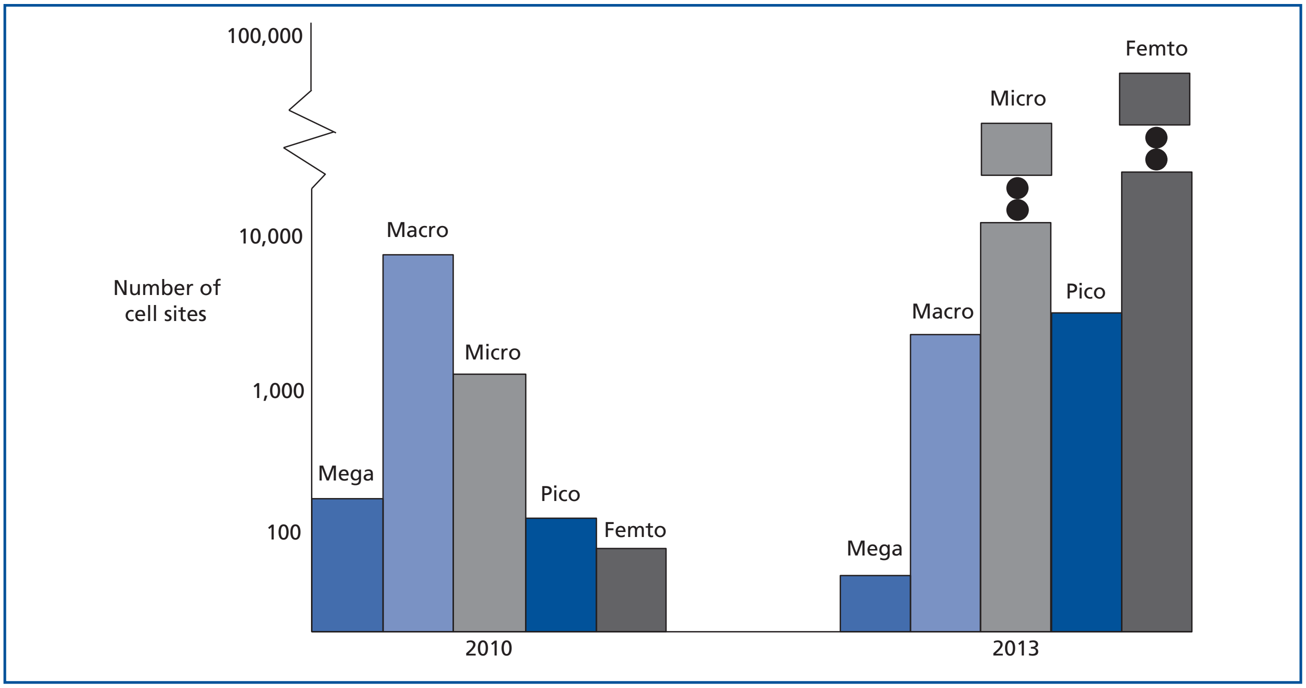

Figure 6.
Evolution of capacity improvement forecast.

would likely be some combination of the four approaches, since these approaches are not mutually exclusive, but rather complementary. There are several other options operators can consider, such as the use of cognitive radio technologies that have the potential to support new features like optimizing the use of spectrum or access to "white spaces" in some markets. Operators will need to employ all these options in the near and longer term in order to address their customers' demand for mobile data. Together, these methods represent the best approach to handling the expected traffic increase in the coming decade.

It is likely that, even if operators increase their capacity within given spectrum through technological innovations as outlined above, additional spectrum will still be required to handle the new mobile data demands. Spectrum will, therefore, remain one of the key elements that will influence the successful deployment of MBB and next-generation wireless technologies to answer the growing demand for ubiquitous, always-on connectivity.

The Spectrum Shortfall

There is already a significant amount of spectrum allocated to mobile services and identified for IMT. According to the ITU Radiocommunication Sector (ITU-R) Radio Regulations (RR), all spectrum identified for IMT can be used for deployment of LTE/LTE-A and other IMT technologies. This includes all the bands originally identified for IMT-2000 and, in addition, the spectrum bands identified in 2007. LTE is currently the technology of choice for many operators and it is being widely deployed in the available spectrum. We anticipate that LTE-A (with time division duplexing (TDD) and frequency division duplexing (FDD) profiles) will be the choice for many operators and that it will be introduced according to their business needs. Some operators in North America and the Asia-Pacific have already announced their intentions to upgrade networks to LTE-A, with commercial systems expected to be deployed starting in 2013 [7, 19].

The spectrum identified for IMT in the RR is at various points in the range between 450 MHz and 3.6 GHz. The total amount of spectrum identified on a regional basis is depicted in **Table I**.

The current amount of spectrum identified for IMT (third column in Table I) is available in the bands identified for IMT in Recommendation ITU-R M.1036 [13], which are shown in **Table II**.

Table I. Spectrum identified for IMT.

ITU Regions	Spectrum identified for IMT prior to 2007 (MHz)	Additional spectrum identified in 2007 (MHz)	Current amount of spectrum identified for IMT (MHz)
Region 1 (EMEA)	693	392	1085
Region 2 (North and South America)	723	432	1155
Region 3 (Asia Pacific)	749	392	1141

EMEA—Europe, Middle East, and Africa
IMT—International Mobile Telecommunications
ITU—International Telecommunications Union

Table II. Specific bands identified for IMT.

Bands identified for IMT in MHz
450–470
698–960
1 710–2 025
2 110–2 200
2 300–2 400
2 500–2 690
3 400–3 600

IMT—International Mobile Telecommunications

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 RR. Different regulatory provisions apply to each band. Moreover, national administrations may deploy IMT systems in bands other than those identified in the RR, and they may deploy IMT systems only in some or parts of the bands identified for IMT.

The spectrum currently used for LTE/LTE-A is located in the frequency range from 698 MHz to 3.6 GHz. However, there is no one-to-one correlation between the spectrum identified for IMT and the spectrum where IMT is deployed in specific countries or regions. This is because sometimes the spectrum identified for IMT is not available for use by IMT (e.g., 2.3 GHz bands in some countries), and sometimes IMT is deployed in spectrum not formally identified for use by IMT (e.g., the 1.5 GHz band in Japan).

In practice, much of this spectrum is very fragmented, and this has resulted in over 40 band classes being defined by 3GPP for LTE/LTE-A. Several of these bands are being used only on a regional or national basis and some of the arrangements are mutually exclusive, therefore not all of them can be implemented in every country.

The combined effect of fragmented and non-harmonized identified spectrum with the mobile data explosion is a significant spectrum shortfall.

In 2007, the ITU-R estimated that the amount of spectrum needed for IMT by 2020 would be in the range of 1.2 GHz to 1.7 GHz [9]. A simple comparison of this figure with the amount of spectrum already identified (as shown in Table I) indicates that 200 MHz to 600 MHz of additional spectrum is required. Given the mobile data explosion, the ITU-R is re-reviewing its spectrum estimates. The amount of that shortfall is still being calculated within the ITU-R, but preliminary estimates range from between 300 MHz to over 1 GHz [15].

Frequencies below 300 MHz would require antenna sizes that would make them inappropriate for use with IMT; and truly mobile applications would not be adapted to bands above around 6 GHz. Therefore, the search for additional spectrum for IMT is focused primarily on the frequency bands between 470 MHz and 4.5 GHz.

When evaluating the spectrum between 470 MHz and 4.5 GHz, the industry tends to consider the bands in three categories, largely based on their propagation characteristics: coverage, capacity, and performance. These are not exclusive categories, as

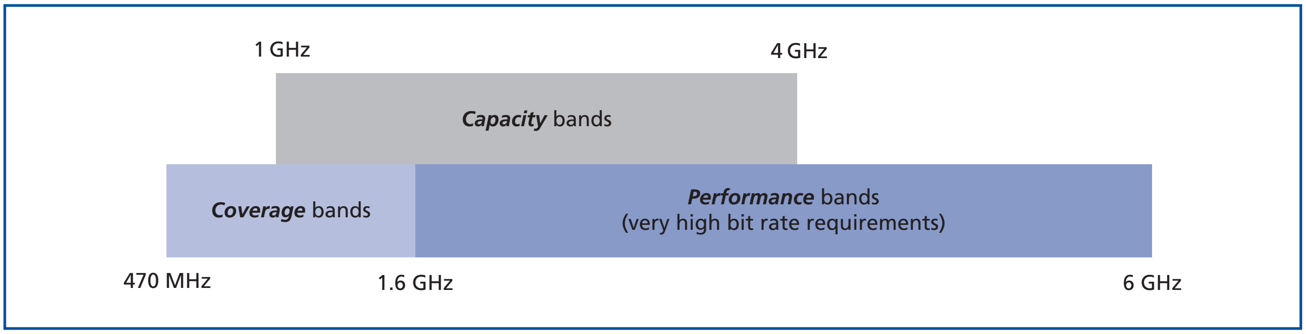

Figure 7.
A schematic illustration of categories in terms of spectrum bands.

there is some overlap depending on the specific usage. **Figure 7** provides a schematic view of categories in terms of spectrum bands.

As shown in Figure 7, the lower frequency bands—those from 470 MHz to approximately 1.6 GHz—are usually categorized as *coverage* bands. The favorable propagation characteristics of lower frequency bands and the associated coverage advantages result in significant savings, particularly for deployment in large areas with low population density or where there is limited existing infrastructure. The lower frequency bands offer the best opportunity to deliver MBB services to rural and remote communities in a more affordable way. In addition, the same propagation characteristics make these bands suitable for deep indoor coverage in dense urban areas.

The higher frequency bands—between approximately 1 GHz and 4 GHz—are often called *capacity* bands. These bands are particularly valuable in areas of high traffic with significant capacity constraints, such as urban areas. The higher frequencies result in smaller cell sizes and more re-use of spectrum. The bands become *performance* bands when there is sufficient spectrum available to enable the realization of full capabilities of technologies like LTE-A, i.e., to enable high data rate transmissions. Due to heavy usage of the lower bands, this spectrum is generally only available above about 1.6 GHz.

A critical consideration is the amount of contiguous spectrum that is available for use by IMT. Realizing the full capability of technologies such as LTE-A necessitates large carrier bandwidths scalable up to 100 MHz. Few of the currently identified bands, with the possible exception of the 3.5 GHz band, have the potential of scaling up to 100 MHz. Even considering the possibility of various carrier aggregation scenarios, operators are going to need large blocks of spectrum in order to deliver on the promise of LTE-Advanced.

A further consideration is the asymmetrical nature of the mobile data explosion. The increase in the amount of downlink traffic (e.g., for video downloads) has outstripped the increase in uplink traffic, resulting in greater asymmetry. This factor must also be taken into account when considering what spectrum should be made available for next-generation wireless systems.

In a nutshell, it is not enough to simply have more spectrum identified. It must be the "right" spectrum—in the right frequency ranges, in the right amounts, in the right proportions to handle future traffic demands. The process of obtaining the "right" spectrum for mobile communications requires complex negotiations in the ITU, as will be detailed in the subsequent sections.

The International Spectrum Allocation Process

The spectrum allocation and assignment process combines respect for the sovereignty of national authorities with the rigor of international treaty negotiations, since frequencies are not geographically delimited and interference can spread over wide distances.

At the international level, the spectrum allocation process is handled by the ITU through its dedicated arm, the ITU-R, which is concerned with radiocommunications and, therefore, with spectrum. The ITU is the United Nations specialized agency for information and communication technologies (ICT) and currently has a membership of 193 countries and over 700 private sector entities and academic institutions. One of the key responsibilities of the ITU-R within the ITU is the organization of World Radiocommunication Conferences (WRCs) at which a worldwide common spectrum allocation framework is agreed. The WRC is held every three to four years to review and revise the RR, the international treaty governing the use of radio-frequency spectrum and satellite orbits. Between WRCs, the various ITU-R Study Groups (SGs) and Working Parties (WPs) perform studies to support the decision making at the WRCs. Alcatel-Lucent is engaged in the ITU-R WRCs, Study Groups, and Working Parties on spectrum-related matters. Alcatel-Lucent chairs two of the groups that contribute to determining the amount of spectrum and the location of the spectrum to be made available for IMT at WRC-15.

The ITU divides the world into three regions: Region 1 includes Europe, the Middle East, and Africa (EMEA), Region 2 covers North and South America, and Region 3 corresponds to the Asia Pacific and China. Each of these regions has one or more regional bodies that coordinate positions on spectrum-related matters for regional implementation and for WRCs. In Region 1 this work is performed in ASMG, ATU, CEPT and RCC. CITEL performs this role in Region 2, while the APT plays a similar role in Region 3. Alcatel-Lucent is active in organizations in all three regions and Alcatel-Lucent internal organizations are aligned to coordinate the activities performed in each region and at the ITU-R.

The actual implementation of the RR and any regional decisions is done at a national level. Most countries have now established independent frequency agencies and regulatory authorities which coordinate the spectrum partitioning, award frequency licenses, and assign frequencies within the country. Alcatel-Lucent engages directly with national regulators through its Global Government and Public Affairs Department and in-country customer teams. Each sovereign nation may take its own approach to implementation of the Radio Regulations. National variation from the Radio Regulations can occur for a number of reasons, including:

- They may be encumbered by existing allocations, (e.g., for military or broadcast services), where incumbents are reluctant to relocate.
- They may be bound by bilateral agreements with neighbors, which may not be reflected in the RR.
- They may have their own regional or national decisions with unique regulatory provisions for the use of the band, including the definition of frequency arrangements, and mandated technical parameters to ensure mutual coexistence with other radio systems.

As a result of these and other factors, ITU allocations are not always followed in national or regional assignments. Fragmented markets, difficulties at borders, roaming limitations, and restrictions in spectrum efficiency often result from variations in the implementation of the RR at the national level.

It is important to note that the ITU-R has no enforcement power over its member states when it comes to implementation of the RR. As long as the allocation is not causing harmful interference to other operations, there are no consequences for not following the Radio Regulations.

Objectives of Alcatel-Lucent's Engagement in the ITU-R and WRCs

One of Alcatel-Lucent's aims, shared by the mobile industry as a whole, is spectrum harmonization at an extended (global or regional) level in order to improve economies of scale in the development of technologies and the manufacture of equipment. Spectrum harmonization fits in with our overall spectrum strategy, which is designed to support two objectives, namely revenue generation and cost reduction for the operators. These objectives can be achieved by executing the following activities:

- Contributing to the revenue potential by harmonizing spectrum as much as possible worldwide, thereby improving economies of scale for the development of technologies and products.
- Creating specific sales opportunities for our products and services by engaging with customers and government administrations on spectrum-related issues.
- Promoting technology neutrality and thereby reducing constraints that might preclude the deployment of some Alcatel-Lucent products in given spectrum.
- Securing identification/allocation of additional spectrum for commercial use in the long-term, consistent with our customers' need to support growth and to provide new services, which will create the opportunity for increased sale of wireless infrastructure.

Key Issues at WRC-15 for Next-Generation Wireless Technologies

Despite the limitations described above, the World Radiocommunication Conferences and their resulting treaties are the best way we have to harmonize the use of spectrum on a global and regional basis. Our work in the ITU-R contributes to the realization of all the above objectives. For example, for the WRC in 2015, Alcatel-Lucent is actively engaged in agenda items (AIs) to secure additional spectrum for IMT, to determine the technical parameters and conditions for deployments of IMT equipment in the 694 MHz to 790 MHz band in EMEA (Region 1), to address the broadband needs of public safety organizations. In addition, Alcatel-Lucent follows five AIs that propose to allow additional services into the spectrum used for microwave backhaul.

In **Table III**, we detail the agenda items that we have identified as having the most significant impact on the next-generation of wireless technologies.

The agenda items relating to additional spectrum for IMT are AI 1.1 and AI 1.2 where, as noted above, Alcatel-Lucent chairs two of the groups that will contribute to determining the amount of spectrum and the location of the spectrum to be made available for IMT.

As mentioned above, studies in support of agenda items are done in the ITU-R Study Groups and Working Parties. **Figure 8** illustrates some of the steps to be followed within ITU-R on Agenda Item 1.1 for WRC-15 [4, 10–12, 14]. Similar, but slightly less complex, processes are underway for each of the agenda items.

Agenda Item 1.3 could directly impact the market for dedicated LTE solutions and equipment for public safety. Alcatel-Lucent chairs the group responsible for this Agenda Item.

Agenda Items 1.6.1, 1.6.2, 1.8., 1.9.1 and 1.10 could all impact the spectrum that operators use for microwave backhaul, which is critical to addressing the increase in data traffic.

Considerations on the Identification of Additional Bands for IMT

As the focus of this paper is on addressing the spectrum shortfall caused by mobile data, some further elaboration on Agenda Item 1.1 is necessary. Currently in the ITU-R, nearly all the spectrum between 470 MHz and 6425 MHz (and even some above) that is not already identified for IMT has been identified as "suitable" for consideration for IMT use. This is before any studies have been performed on whether or not IMT can share the spectrum with the existing services in the bands. Clearly, in the end, some bands will not be suitable because important (e.g., public safety) services are already using the bands. However, some other bands will be considered for IMT. The identification of bands for IMT is a lengthy process that looks at both technical and commercial aspects to evaluate the advantages and disadvantages of each band. Below are some of the issues currently being discussed in the ITU-R in relation to various spectrum bands:

- *Coverage bands (between 470 MHz and approximately 1.6 GHz)*. The main appeal of the coverage

Table III. Most important AIs at WRC-15 for next-generation wireless technologies.

Scope	Agenda item	Description of the item	Potential impact on next-generation wireless technologies
Determine the amount of spectrum and the location of the spectrum to be made available for IMT	***AI 1.1***	To consider additional spectrum allocations for mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with **Resolution 233 *(WRC-12)***.	Securing additional spectrum for IMT to address the mobile data explosion.
	AI 1.2	To examine the results of ITU-R studies, in accordance with **Resolution 232 *(WRC-12)***, on the use of the 694–790 MHz mobile frequency band, with the exception of aeronautical mobile service, in Region 1 and take the appropriate measures.	Determining the technical parameters and conditions for deployment of IMT equipment in the 694–790 MHz bands in EMEA (Region 1).
LTE solutions and equipment for public safety	***AI 1.3***	To review and revise **Resolution 646** (**Rev. *WRC-12***) for broadband public protection and disaster (PPDR) in accordance with **Resolution 648 *(WRC-12)***.	Offering the possibility of identifying new spectrum for public safety and/or harmonizing existing spectrum, which would facilitate deployment of public safety equipment, i.e., LTE FDD.
Consider possible new uses for spectrum that mobile operators currently use for microwave backhaul, which is critical to addressing the increase in data traffic	***AI 1.6.1***	To consider possible additional primary allocations to the fixed-satellite service (Earth-to-space and space-to-Earth) of 250 MHz in the range between 10 GHz and 17 GHz in Region 1.	Protecting operators' networks from possible additional interference that might result from expanded use of fixed-satellite service networks in 10–17 GHz in Region 1.
	AI 1.6.2	To consider possible additional primary allocations to the fixed-satellite service (Earth-to-space) at 250 MHz band in Region 2 and 300 MHz band in Region 3 within the range 13–17 GHz; and review the regulatory provisions on the current allocations to the fixed-satellite service within each range, taking into account the results of ITU-R studies in accordance with **Resolutions 151 *(WRC-12)* and 152 *(WRC-12***), respectively.	Protecting operators' networks from possible additional interference that might result from expanded use of fixed-satellite service networks in 13–17 GHz frequencies in Region 2 and Region 3.
	AI 1.8	To review the provisions relating to earth stations located on board vessels (ESVs), based on studies conducted in accordance with **Resolution 909 *(WRC-12)***.	Protecting operators' networks from possible additional interference that might result from expanded use of ESVs using fixed-satellite service networks in the 5925–6425 MHz and 14–14.5 GHz uplink bands.
	AI 1.9.1	To consider, in accordance with **Resolution 758 *(WRC-12)***, possible new allocations to fixed-satellite service in the frequency bands 7150–7250 MHz (space-to-Earth) and 8400–8500 MHz (Earth-to-space), subject to appropriate sharing conditions.	Protecting operators' networks from possible additional interference that might result from new allocations to FSS.
	AI 1.10	To consider spectrum requirements and possible additional spectrum allocations for mobile-satellite service in the Earth-to-space and space-to-Earth directions, including the satellite component for broadband applications, including International Mobile Telecommunications (IMT), within the frequency range from 22 GHz to 26 GHz, in accordance with **Resolution 234 *(WRC-12)***.	Protecting operators' networks from interference that might possibly result from any new MSS allocations.

AI—Agenda Item
COM—Committee
EMEA—Europe, Middle East, and Africa
ESVs—Earth stations on board vessels
FDD—Frequency division duplex
FSS—Fixed satellite service
IMT—International Mobile Telecommunications
ITU—International Telecommunication Union
ITU-R—ITU Radiocommunication Sector
LTE—Long Term Evolution
MSS—Mobile-satellite service
WRC—World Radiocommunication Conference

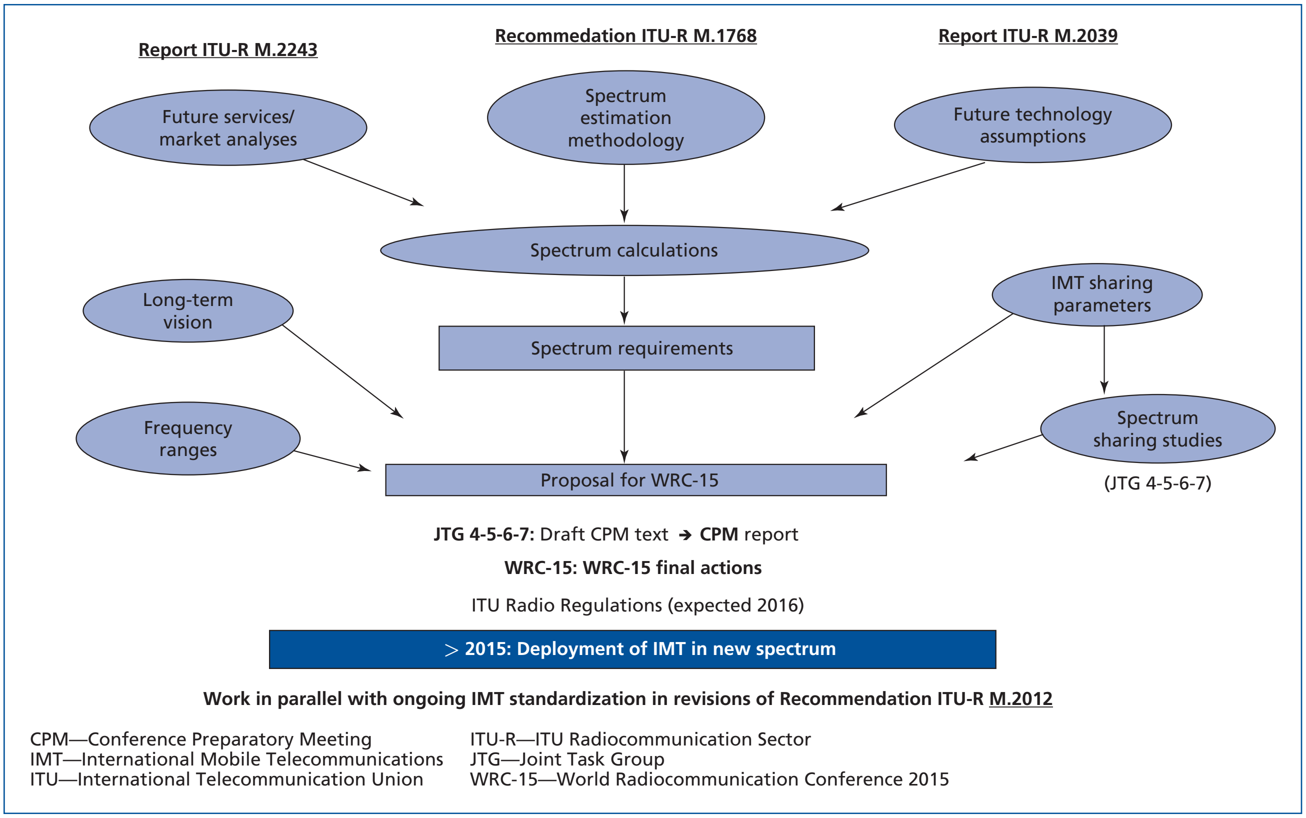

Figure 8.
IMT activities toward WRC-15 Agenda Item 1.1.

bands is the impact the propagation characteristics could have on the number of cell sites required to cover a given area and, thus, on cost effective deployment in certain areas (e.g., rural). As the number of cells required increases, the cost of deployment will increase, which can lead to higher costs for operators and consumers. In low user density areas, the relationship between the numbers of cells required for coverage and the frequency band will depend on the assumed propagation law (all other things being equal); therefore, the exact frequency range is important in order to allow cost-effective deployments. Even small differences of one dB can increase the number of cells required in a low user density area by 10 percent to 15 percent. Analysis shows that, even in the most optimistic propagation model, every doubling of the operating frequency would reduce the coverage area by 50 percent, which would require doubling the base station density to restore full area coverage [16].

From the handset perspective, the limitation in size sets a lower practical limit on frequency suited for mobile devices as there is a need to have efficient antennas, and the increased wavelength at lower frequencies translates into bigger antennas.

- *Capacity bands (1 GHz to 4 GHz).* In the deployment of radio networks, it is usually the case that cells in urban and suburban areas will not be noise/range limited (as rural cells are), but capacity limited. In this case, the size of the cell will be driven by the traffic offered per unit area and the

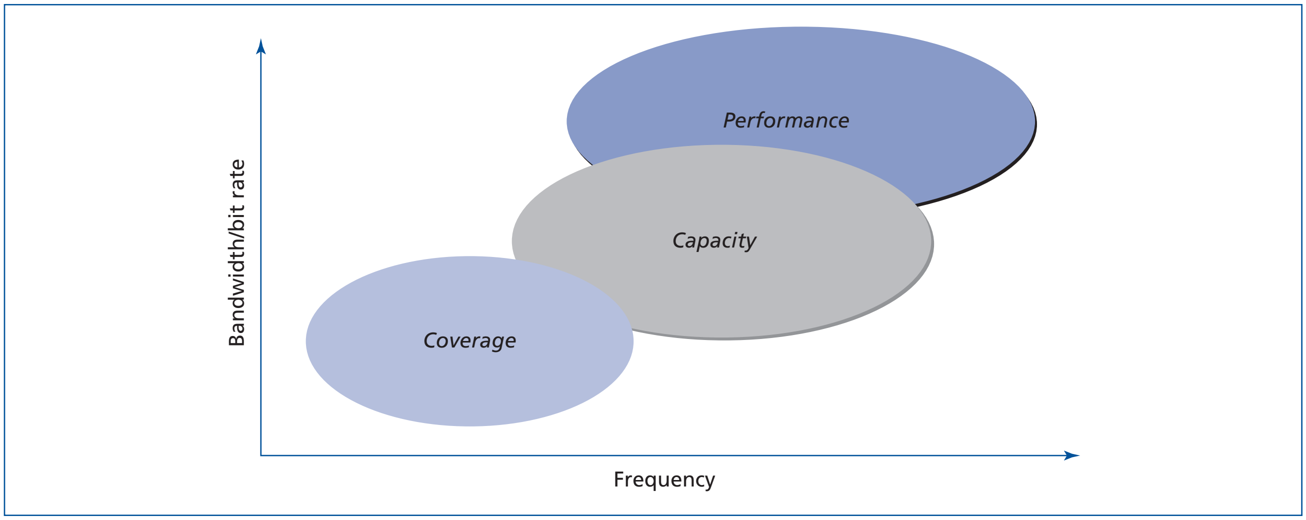

Figure 9.
Conceptual diagram of spectrum categories.

capacity of a cell per unit area. Therefore, the size of a cell will need to be matched to cater to the traffic offered per unit area. The lack of sufficient capacity spectrum is translated into a limitation in the networks' offered data rate to consumers, or in the need to deploy a large number of extra smaller cells in urban/suburban areas. Densification with small cells to compensate for the required data rates may increase costs, and the acquisition of such sites in the required location may be difficult.

The exact frequency range required for capacity spectrum will be influenced by a number of factors such as radio frequency (RF) component availability. The technical and economic feasibility of very large RF components may be challenging. Careful evaluation must be done of the tradeoff between the need for wide frequency ranges to accommodate higher capacities and the feasibility and cost of the RF components to realize it [16].

- *Bands for very high bit rate requirements.* IMT-Advanced is designed to meet the requirements for higher data rates to be made available to consumers: data speeds above 100 Mbit/s for high mobility users and approaching 1 Gbit/s for low mobility users for "nomadic/local wireless access" [8]. Achieving such speeds will require large contiguous blocks of spectrum. Since this spectrum is more likely to be available at higher frequencies, to enable the efficient provisioning of data rates above 100 Mbit/s, operators will have to use the spectrum for small cells. Provisioning of very high bit rates will require a combination of large bandwidth carriers, signal-processing techniques to reduce other cell interference, and massive MIMO to provide the degrees of freedom needed [16].

The spectrum categories mentioned above are not mutually exclusive, and operators will require a combination of coverage, capacity, and performance bands to answer the challenges of geographical coverage and capacity requirements. It should be noted, however, that there is no strict definition of the spectrum categories, since some bands can address needs depending on the specific situation (type of demand, available amount of spectrum, morphology, and other cases) as illustrated in **Figure 9**.

Conclusions

This paper has examined the current situation in which mobile data traffic is increasing dramatically and has outlined alternative options to support the demand for mobile connectivity. The introduction of new MBB technologies, such as LTE-Advanced, responds partially to the demand; however, technology alone cannot meet this demand. Success depends, therefore, on the availability of both advanced technologies and spectrum beyond that which is currently available for cellular mobile systems.

The ITU, as the global body that manages the allocation of spectrum, is working through its Radio Communication division to make spectrum available in the different regions. The identification of globally harmonized bands, or at least regionally harmonized bands and channel arrangements, requires efforts that are collectively supported by the mobile ecosystem and industry. Alcatel-Lucent supports, through its contributions and leadership in the ITU, the harmonization efforts and the identification of additional spectrum for mobile communications. Achieving such goals can be translated into improved internal economies of scale for the development of new technologies and products.

Moreover, Alcatel-Lucent focuses on delivering positive results for the company and our customers through engagement on WRC-15 agenda items. This brief outline of the company's involvement in these activities aims to familiarize the reader with the complex WRC process and the commitment Alcatel-Lucent has within the ecosystem and its customers.

Last, but not least, since spectrum is a scarce resource that is internationally available but nationally managed, Alcatel-Lucent commits to support the global effort of optimizing the allocation and use of the radio airwaves to provide the best societal and economic benefits for citizens, governments, and for the telecommunication industry as a whole.

Acknowledgements

The authors would like to acknowledge the great effort of Mirela L. Doicu of the Alcatel-Lucent International/Global Government and Public Affairs Department for her constructive comments in order to improve the paper significantly.

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(Manuscript approved March 2013)

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