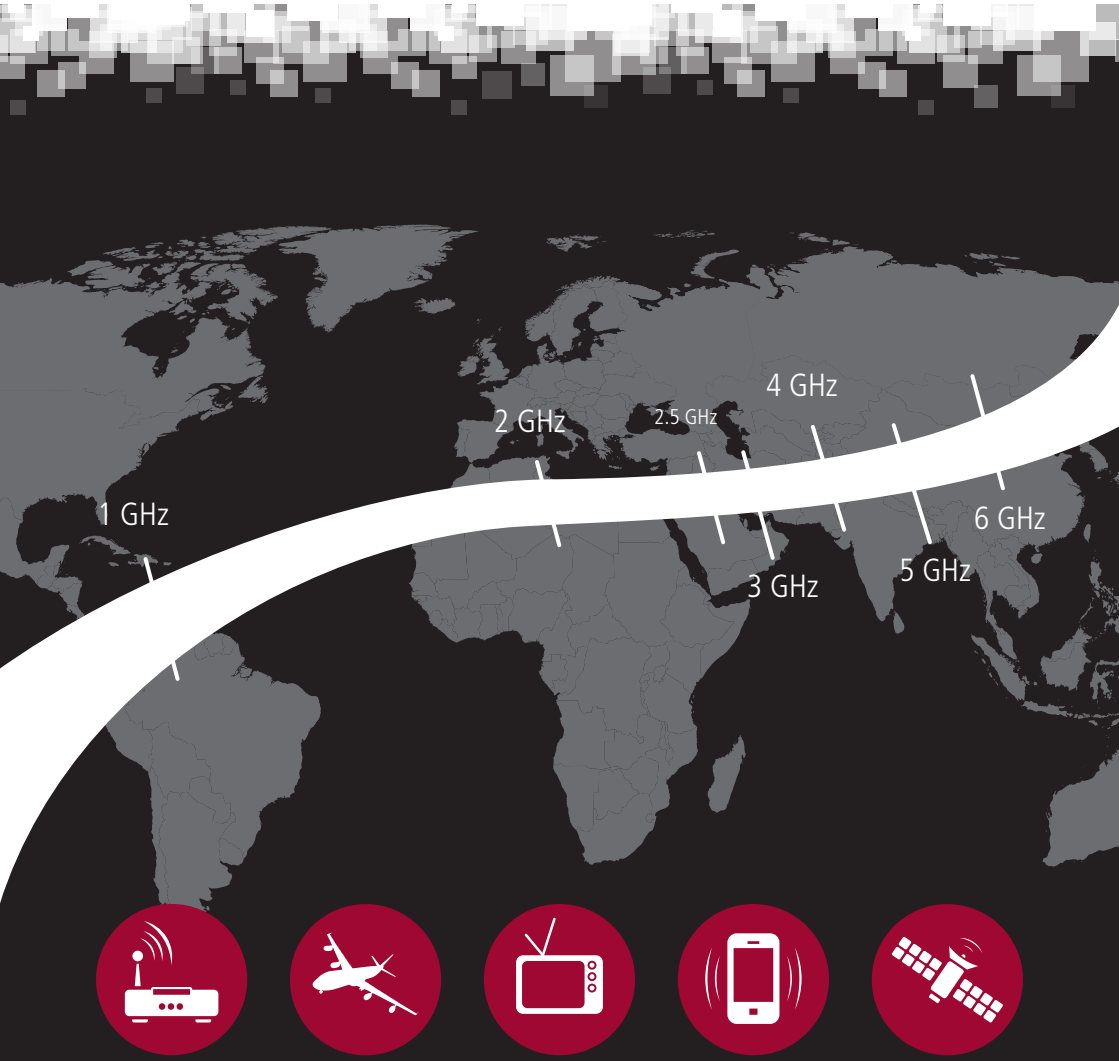
Spectrum Handbook

Understanding the Basics of Spectrum Policy for Mobile Telecommunications



December 2011

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Why Spectrum Matters

Society benefits in countless ways from devices that communicate over the airwaves. Radio frequency spectrum is used to send information instantly across distances short and long — without wires or cables — making things possible that most people take for granted: television and radio, mobile phones, airplane navigation and radar, and Wi-Fi connections in airport lounges. Wireless technologies are ubiquitous, and people have come to depend on them in an increasingly connected, information-driven world.

Now that mobile phones have become pervasive around the world, the boom is in mobile data, as people are using smartphones to access the internet, send and receive email, watch videos and use mobile apps. In fact, mobile data traffic is projected to grow annually by 92 per cent, through 2015, according to Cisco Systems.[1] The mobile industry is growing by leaps and bounds.

Mobile penetration is directly linked to economic growth, and not only in developed economies. One study found that a 10 per cent increase in mobile penetration in a developing country typically leads to a 1.2% growth in its GDP.[2]

However, the portion of the radio spectrum that can be used for many services is very limited. With so much at stake, for society and national economies, responsible management of this valuable resource is critical.

About this handbook

This handbook gives a nontechnical introduction to radio spectrum and the issues surrounding spectrum management, for people who don't have a technical background in the subject. While there is far more to know about spectrum than is contained in these pages, it is hoped that this overview will be a useful primer.

> The 'mobile miracle' is putting ICT services within reach of even the most disadvantaged people and communities. Our challenge now is to replicate that success in broadband.
>
> — ITU Secretary General Hamadoun Touré

[1]Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010–2015
[2]GSMA Global Mobile Tax Review 2006-07

Radio Frequency Spectrum Explained

Radio waves are a form of electromagnetic radiation which, like visible light or infrared, make up one portion of the entire spectrum. They cannot be perceived by human eyes or ears, and they are not harmful in the environment. Depending on their frequency, radio waves can pass through solid objects and travel long distances. This makes them useful for mobile communications, broadcasting and many other wireless applications.

Radio waves can be characterised by their wavelength or frequency, but frequency is usually used today. The frequency is measured in Hertz (or Hz) — the number of waves or cycles that pass in a second. For most radio signals, this number is very high, so it is usually abbreviated:

- kiloHertz (or kHz), thousands of cycles per second
- megaHertz (or MHz), millions of cycles per second
- gigaHertz (or GHz), billions of cycles per second

The radio spectrum ranges from very low frequency radio waves at around 10kHz (30 kilometre wavelength) to millimetric waves at up to 100GHz (3 millimetre wavelength). The radio spectrum is



How Mobile Phones Work



A mobile phone sends and receives information (voice or data) by radio communication.

Base stations are positioned in networks of overlapping cells, to ensure mobile phone users are always within range of a base station.

divided into frequency bands, with each band reserved for a single use or a range of compatible uses. Within each band, individual transmitters often use separate frequencies, or channels, so that they do not interfere with each other.

Not all radio frequencies are equal. In general, lower frequencies can reach further beyond the visible horizon, and are better at penetrating rain or buildings. On the other hand, the capacity of a of a wireless connection for data or voice calls is dependent on the amount of spectrum that it uses — the channel bandwidth — and wider channel bandwidths are more readily available at higher frequencies. For many wireless applications, the best trade-off of these factors occurs in the frequency range of roughly 400MHz to 4GHz, and there is great demand for this portion of the radio spectrum.

How devices communicate

Regardless of their function, all communication devices that use digital radio transmissions operate in a similar way. A transmitter generates a signal that contains encoded voice, video or data at a specific radio frequency, and this is radiated into the environment by an antenna, or aerial. This signal spreads out in the environment, and a small proportion is captured by the antenna of the receiving device, which then decodes the information. The received signal is incredibly weak — often only one part in a trillion of what was transmitted.

In the case of a mobile phone call, a caller's voice is converted by the handset into digital data, transmitted via radio to the network operator's nearest tower or base station, transferred to another base station

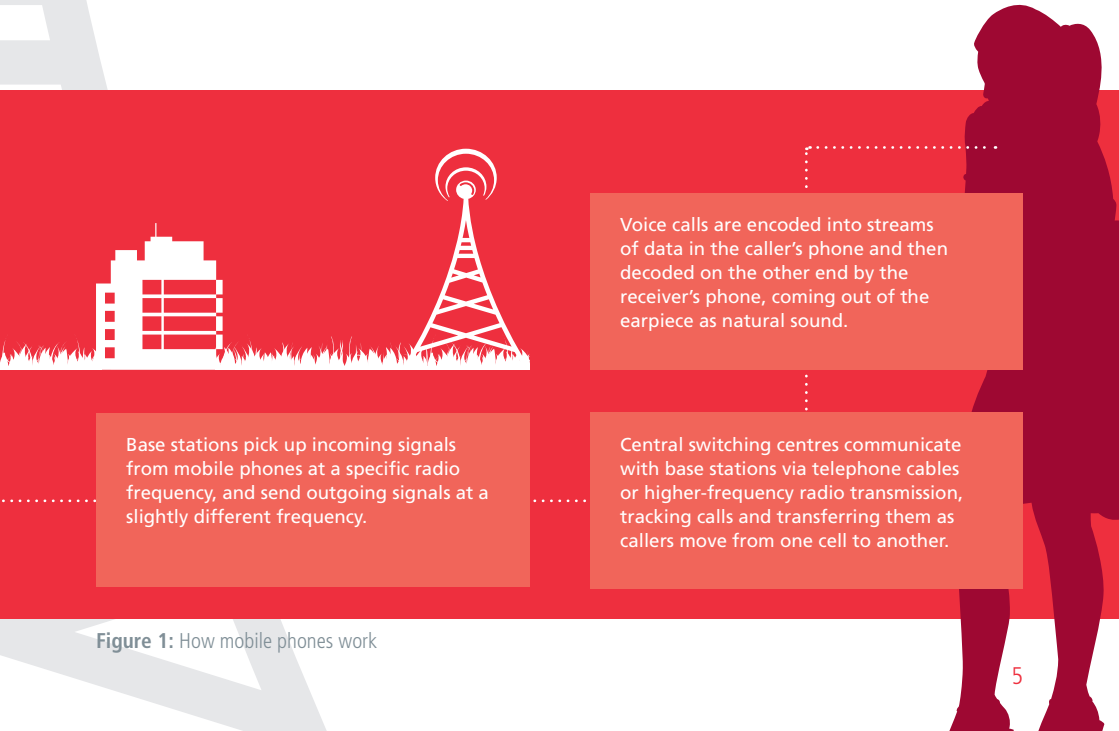


Figure 1: How mobile phones work

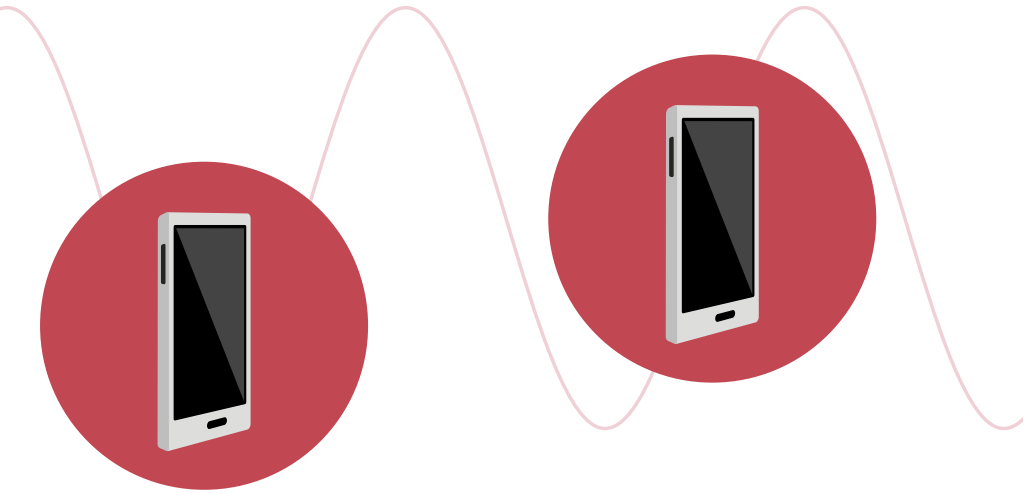
serving the recipient's location, and then transmitted again to the recipient's phone, which converts the signal back into audio through the earpiece.

There are a number of standards for mobile phones and base stations, such as GSM, WCDMA and LTE, which use different methods for coding and decoding, and ensure that users can only receive voice calls and data that are intended for them.

Co-location of services

Because there are so many competing uses for wireless communication, strict rules are necessary to prevent one type of transmission from interfering with the next. And because spectrum is limited — there are only so many frequency bands — governments must oversee appropriate licensing of this valuable resource to facilitate use in all bands.

Governments spend a considerable amount of time allocating particular frequencies for particular services. These allocations are agreed internationally, so that interference across borders, as well as between services, is minimised.



A Resource in High Demand

Radio frequency spectrum is used for a wide range of purposes, for things like keeping people safe (military and police), in touch (mobile phones), on course (GPS navigation) entertained (radio and television broadcasting) and online (mobile broadband and Wi-Fi).

What is spectrum used for?

Wireless consumer products, including mobile phones, use a very small percentage of the total radio spectrum. Some other uses that are closely tied to everyday life include:

- Terrestrial broadcast television and radio
- Satellite broadcasting
- Location systems like GPS
- Wi-Fi
- Remote car keys
- Cordless phones

However, most spectrum is allocated to government and industrial uses that consumers don't directly see, such as:

- Military and national security systems
- Satellite communications
- Maritime communications and navigation
- Aviation systems and air traffic control
- Weather radar
- Radio astronomy

But the most dynamic, fast-growing use of spectrum is mobile voice and data. The mobile phone has become the most widespread communication platform of any kind in history. In 1995, there were about 5 million mobile connections worldwide. By the end of 2011, mobile connections are expected to surpass 6 billion, with the most recent billion achieved in only 16 months.

Ownership and licensing

Governments own and manage the use of radio frequency spectrum within their territory. In most cases, specific portions are licensed to organisations that want to make use of them for rolling out a wireless network and providing services such as broadcasting or wireless (mobile) broadband.

Licences to use parts of the spectrum are granted by the governing authority in a number of ways: auctions, payment-in-kind auctions ('beauty contests') and sometimes by a first come, first served approach.

Licences define spectral dimension, geographic dimension and time dimension (expiry) of a spectrum usage right, and technically define the usage right for managing interference. Sometimes additional conditions such as fees and charges, as well as coverage and roll-out requirements, are imposed in licenses too.

To encourage more economically efficient and technically effective use of spectrum resources, some governments are liberalising the regulatory framework for spectrum management, removing restrictions and enabling more flexible, market-driven use.

This has seen legislation in some countries allowing the use of spectrum on a more technology-neutral basis, meaning that rather than defining one specific service or technology in the terms of the licence, companies are allowed to use technologies that can co-exist within the technical definition of a license, e.g., defined by a spectrum mask.

Promoting dynamic efficiency, some governments have passed legislation that allows companies that hold spectrum to (fully or partly) trade it. This promotes innovation and increases the efficiency with which the valuable resource is used, as companies are not forced to hold on to spectrum they are not using.

To encourage innovation and competition — generating the greatest value for society and its consumers stemming from use of the spectrum resources — award procedures must be carefully designed and implemented according to principles of transparency and predictability.



Figure 2: Radio frequency spectrum is used for a wide range of purposes, for things like keeping people safe (military and police), in touch (mobile phones), on course (GPS navigation) entertained (radio and television broadcasting) and online (mobile broadband and Wi-Fi).

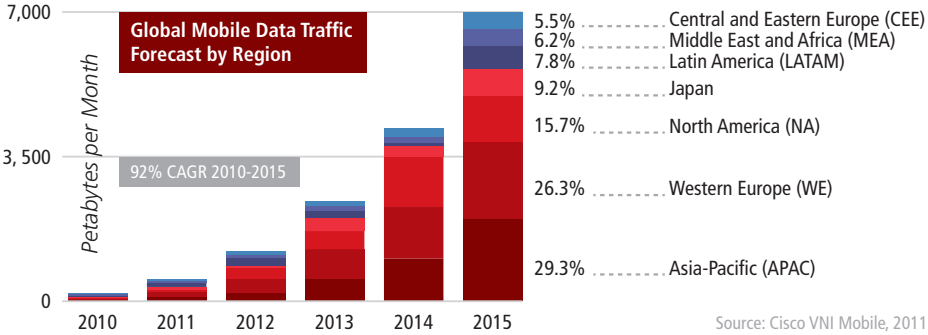
Mobile Technologies and Spectrum Use

The speed with which mobile technology has permeated global society is a testament to the value people place on a connected life. Whether for personal connections or practical activities, doing business or just for fun, mobile phones and devices have become a necessity for at least half the people on the planet.

And the growth of mobile is not flagging. One billion mobile connections are being added every 16 months, of which 40 per cent are 3G connections, allowing mobile internet browsing. So not only are the total number of subscriptions on a steep incline, but the migration from voice-only 2G mobile technology to 3G voice-plus-internet is well underway around the globe. Approximately 2.8 billion 3G connections are expected by 2014. This shift to mobile data is happening in emerging markets as well as wealthier economies.

Mobile connectivity is not limited to phones and wireless tablets. It is transforming the way people use all kinds of machines and devices. Health monitors, cameras and cars can all use an embedded mobile connection to transmit information about their location, their performance and their usage, opening up the potential for new services, enriching people's lives and making organisations more effective.

In addition to the ever-growing demand for mobile broadband, new applications for mobile are emerging all the time. Although not heavy on data traffic, the sheer number of these types of services will continue to fuel demand for



Source: Cisco VNI Mobile, 2011

Figure 3: The volume of mobile data is growing by approximately 92 per cent, year over year.

spectrum coverage just as much as for capacity:

- Mobile money is a service that uses mobile technology to bring together the financial and mobile industries. This includes applications such as Pay-Buy-Mobile, which enables phones to make payments using near field communications — similar to a swipe card — for things like buying a ticket for public transport or supermarket shopping. A different application, Mobile Money Transfer, allows people without access to banking facilities to use their phones to make electronic payments, which is of particular benefit to people in rural areas and developing countries.

- mHealth comprises a variety of existing and emerging products that enhance quality of care and wellness, while in many cases reducing healthcare costs. Such devices include vital sign monitors, location/motion sensors, caregiver solutions, medication adherence products and remote consultation systems.

- Automotive. As the world's roads become increasingly congested, smarter, connected vehicles are able to alert drivers about road and weather conditions, or automatically alert emergency services when an accident has occurred. By 2020, more than 1 billion cars will be embedded with a mobile connection.

Other areas offer even more potential. mGovernment solutions are being deployed to enhance the delivery of public services, especially in rural areas. mEducation uses mobile connectivity to create new ways of teaching and learning.

Surprisingly, for all these applications, mobile uses only a small percentage of radio frequency spectrum — while supporting a $1 trillion industry. Mobile is therefore an employment engine and an important driver of innovation.

Meanwhile, the appetite for mobile data keeps getting bigger. Mobile operators are having to make major capital investments to keep pace with demand. Spectrum is the resource that makes this revolution possible — and making the most efficient use of what we have is of critical importance.

> We must unleash spectrum and the opportunity of mobile broadband. Spectrum is our invisible infrastructure; it's the oxygen that sustains our mobile communications.
>
> — US Federal Communications Commission Chairman Julius Genachowski

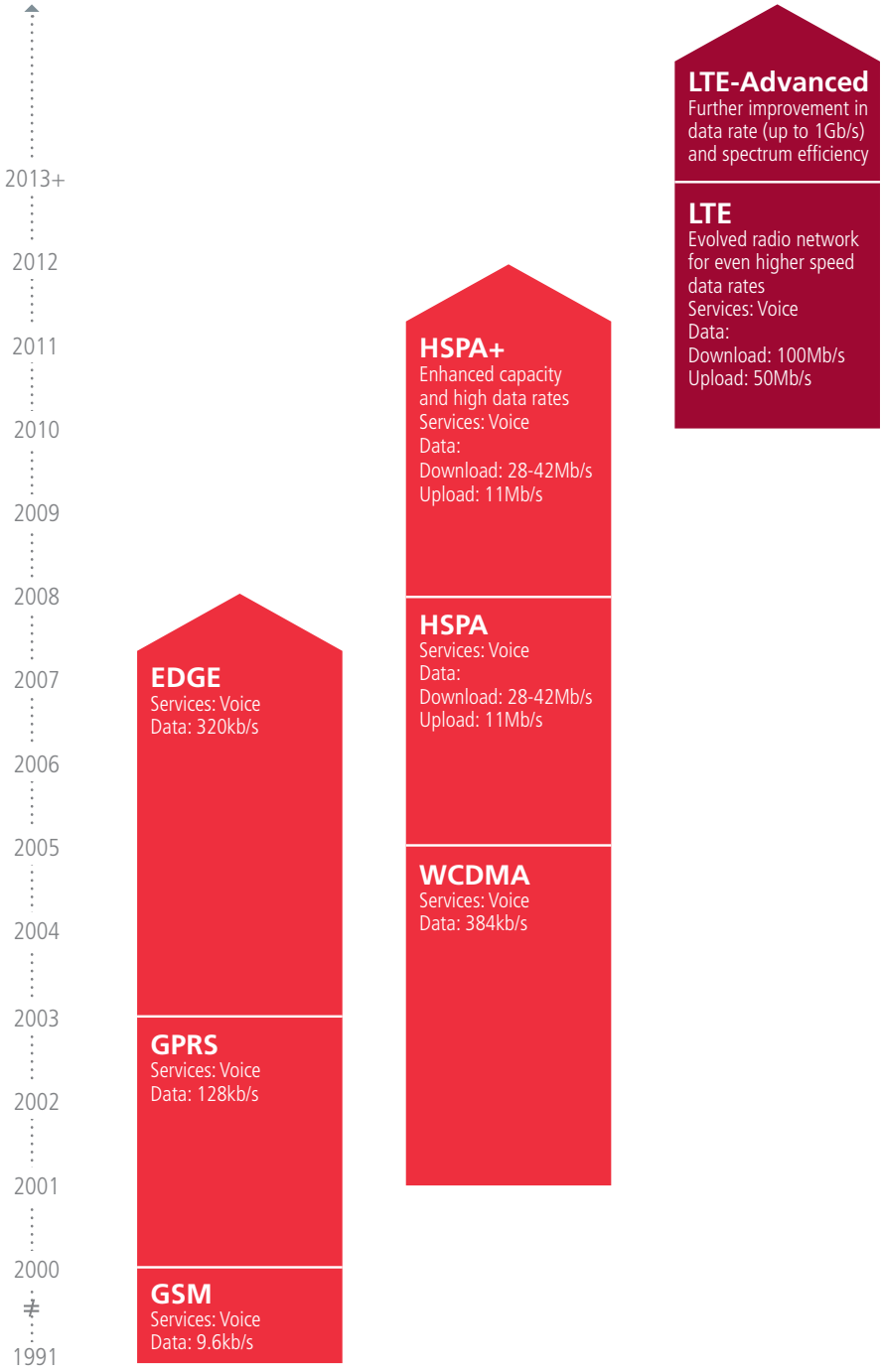


Figure 4: Mobile technology has continually advanced, achieving ever-greater upload and download speeds and more efficient use of available spectrum.

The Evolution of Mobile Technologies

Mobile technology is peppered with acronyms. And spelling out the terms fully usually doesn't help nontechnical people understand what they mean. That said, it's important to master the basics, in order to have a view of how mobile technology has evolved, and which technologies are in use today or on the horizon. Refer to the glossary for additional definitions.

GSM is a second-generation digital, cellular technology used for transmitting voice and data services, first developed in 1991. The GSM family of mobile technologies has been continually enhanced to deliver an increasing range of services, to increase performance and to meet the growing demand. GSM is now used in over 220 countries and territories, serving more than 5 billion people, and provides travellers with access to mobile services wherever they go.

GPRS is a widely deployed wireless data service used today with most GSM networks. This was the first packet technology, enabling data speeds of around 128kb/s.

EDGE technology was a further enhancement to GSM networks, providing up to three times the data capacity of GPRS.

WCDMA enables continued support of voice and text services, in addition to richer multimedia services, including faster internet access.

HSPA is part of the 3G network and is predominately a software upgrade of the 3G network infrastructure. HSPA provides very efficient voice services in combination with mobile broadband data. The speed can vary from 1.8Mb/s up to 28Mb/s.

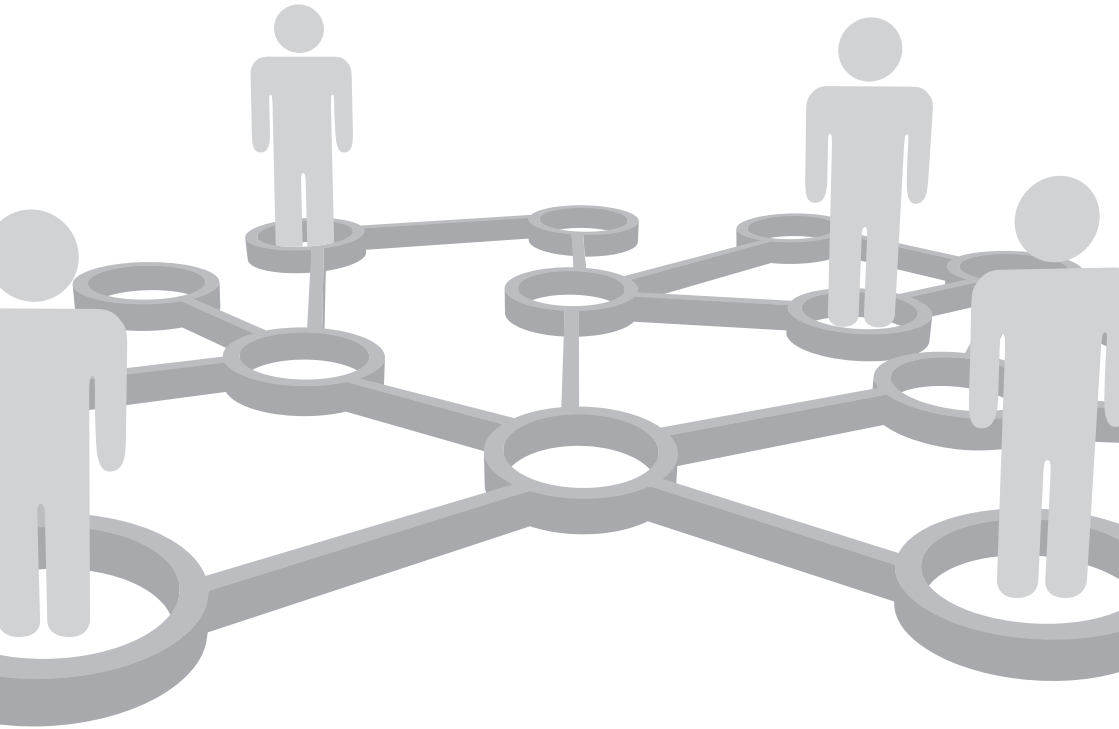
HSPA Evolved (or HSPA+) offers greater throughput and higher performance, with data services enabling download speeds of up to 42Mb/s and upload speeds of 11Mb/s. Higher speeds up to 84Mb/s can be achieved with appropriate, larger chunks of spectrum.

LTE, or long-term evolution, is the next generation of mobile technology that will enable much higher download speeds of up to 100Mb/s to be achieved along with much faster response time making video conferencing watchable. LTE has the advantage of being backward-compatible with existing GSM and HSPA networks, enabling mobile operators deploying LTE to continue to provide a seamless service with legacy networks.

Many operators have not yet upgraded their basic 3G networks, and the choice is very open to allow faster speeds on both HSPA and LTE upgrades. The decision on which technology to deploy

will be based on many criteria including spectrum availability, competitive landscape and device availability. The use of either technology will provide sufficient data capabilities for many years, until the next standard — LTE-Advanced — is mature.

LTE-Advanced extends the technology behind LTE into a further improvement in data rate and spectrum efficiency by making use of fragmented bands. Peak data rates could reach 1Gb/s. LTE-Advanced has now been submitted to the ITU as a candidate technology for IMT-Advanced.



International Regulators and Initiatives

Spectrum licensing is conducted at national level, but radio waves do not stop at national borders, and this means that spectrum management must be international. The mobile industry is working towards establishing region-wide spectrum bands for mobile to provide massive economies of scale and bring manufacturing and end-user costs down. It is also concerned with industry-wide issues such as cross-border interference.

The **International Telecommunications Union (ITU)** is the United Nations agency for information and communication technologies (ICTs). It has three sectors — Radiocommunication, Standardisation and Development. One of the key responsibilities of the Radiocommunication Sector is the Radio Regulations, a treaty governing the international use of the radio spectrum. This is updated by World Radiocommunication Conference (WRC), which convenes roughly every four years, at which governments determine changes to the allocation of spectrum to different services in the future.

There are six Regional Groups that develop proposals at the regional level to be brought to the WRC.

- **Asia Pacific Telecommunity**: Covering the Asian and Pacific regions
- **Arab Spectrum Management Group**: Covering the Arab states in the Middle East and North Africa
- **African Telecom Union**: Covering all of the administrations on the African continent
- **European Conference of Postal and Telecommunications Administrations (CEPT)**: Comprising 48 member administrations including all of the EU countries, Russia and Turkey
- **Inter-American Telecomunications Commission (CITEL)**: Covering the Americas and the Caribbean
- **Regional Commonwealth in the Field of Communications (RCC)**: Covering the Russian Commonwealth of Independent States, as well as the Baltic states which have observer status

Harmonisation

Spectrum harmonisation is the use of the same radio frequency band for the same purpose in a number of countries. This creates economies of scale for the manufacture of mobile/wireless devices, reducing their price, and therefore bringing more products and services to more people. Harmonisation enables people to use their mobile phones when they travel abroad. It also reduces interference issues along national borders.

Spectrum harmonisation should ideally take place at a global level, because this

provides the greatest benefit. However, this has often not been possible, because of differences in the legacy uses of the bands.

Harmonisation is a key objective for the ITU, national regulators and the whole of the mobile industry. Spectrum harmonisation — combined with widely adopted international standards — is what drives the remarkable growth and uptake of mobile technology.

Digital Dividend — the coverage band

Digital television broadcasting requires less spectrum than traditional analogue television. Countries that are phasing out analogue television have an unprecedented opportunity to allocate a block of high-quality, which is able to cover wide geographic areas due to its relatively low frequency. The surplus spectrum is known as the Digital Dividend. Allocation of Digital Dividend spectrum to mobile will drive significant economic and social benefits and is a unique opportunity to bring broadband to all areas.

2.6GHz band — the capacity band

The ITU has identified the 2.6GHz spectrum band for mobile broadband use globally. Governments are being urged by the mobile industry among others to allocate 190MHz within this band to mobile broadband services as soon as possible. The 2.6GHz band is unique in that it could become a common global band for commercial mobile broadband services. This ultimately leads to equipment makers realizing the ability to achieve global economies of scale, lowering the cost of devices and network infrastructure.

900/1800MHz band

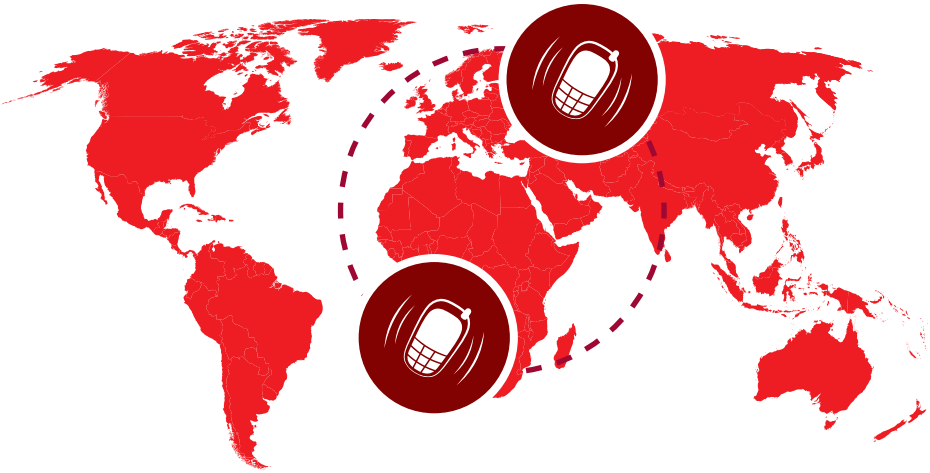
One widely debated issue is the reorganisation of existing 2G spectrum bands held by mobile operators — typically in the 900MHz and 1800MHz ranges — to accommodate growing 3G traffic. Known as 'refarming', this would provide much-needed 3G bandwidth with wide coverage, and a path for supporting 2G voice and data until those services are outmoded.

Managing Spectrum for the Long Term

Responsible oversight of a country's radio frequency spectrum is hugely important, balancing societal needs and benefits, ensuring efficient use, promoting innovation and ensuring competition in relevant downstream markets. For distribution of spectrum between sectors, a wide range of stakeholders, with their own agendas, lobby for positions that support their goals.

But it takes a long time to change course once allocation and regulation decisions have been made. Spectrum regulators, therefore, must keep the following considerations in mind:

- **Economic analysis.** Regulators should have the capability to conduct appropriate analysis of the economic and societal impact of spectrum decisions, in order to give priority to spectrum uses that deliver the greatest benefit to the society and its consumers.
- **A level playing field.** The release of spectrum should allow an equal opportunity for all to compete for spectrum, under rules that foster competition and innovation.
- **Allocation of appropriate bands.** Mobile networks use spectrum for both coverage and capacity. Therefore, efficient spectrum allocation must take these factors into account.
- **Consistency and transparency.** A stable and predictable environment with transparent and open processes will foster market confidence and reduce risk.



Additional Resources

GSM World, Spectrum:
http://www.gsmworld.com/our-work/public-policy/spectrum/index.htm

GSM World, Public Policy:
http://www.gsmworld.com/our-work/public-policy/

GSMA Mobile Broadband:
http://www.gsmamobilebroadband.com/

Embedded Mobile — Automotive:
http://www.gsmaembeddedmobile.com/automotive/

Embedded Mobile — Education:
http://www.gsmaembeddedmobile.com/mobile-education/

Embedded Mobile — mHealth:
http://www.gsmaembeddedmobile.com/health/

GSM World — Mobile Money:
http://www.gsmworld.com/our-work/mobile_lifestyle/mobile_money/index.htm

International Telecommunications Union:
http://www.itu.int/

Asia Pacific Telecommunity:
www.apt.int/APTAPG

Arab Spectrum Management Group:
www.asmg.aeAfrican Telecom Union: www.atu-uat.org

CEPT:
http://www.cept.org/ecc/groups/ecc/cpg

CITEL:
http://portal.oas.org/Topic/CITEL/tabid/378/Default.aspx

RCC:
http://www.en.rcc.org.ru/

Glossary of Terms

3G	The third generation of mobile phone technologies covered by the ITU IMT-2000 family
3GPP	3rd Generation Partnership Project, the body which defines the standards for GSM, WCDMA, and LTE families of technologies
Base Station	A base station is used for linking mobile devices to a wireless carrier's network. A base station provides local coverage and may be many miles or just a few city blocks. The coverage can be in all directions, or the antennas may be aimed only in one direction.
Channel	The amount of spectrum used for transmission of a radio signal. For example, a GSM channel is 0.2 MHz wide, a WCDMA channel is 5 MHz wide and a LTE channel can be up to 20MHz wide.
Digital Dividend	The portion of the UHF broadcast spectrum that is no longer required when television broadcasting switches from analogue to digital transmission
EDGE	Enhanced Data rates for Global Evolution — an enhancement to GPRS, enabling data to be delivered at rates up to 384 kb/s
GPRS	General Packet Radio Service — the component of GSM for data transport
GSM	Global System for Mobile Communications — the 2G technology used throughout Europe and most of the world
GSMA	The GSM Association, representing mobile operators that serve more than 5 billion customers in more than 220 countries
HSPA	High-speed packet access — a technology to efficiently transport data over WCDMA
IMT	Third- and fourth-generation mobile technologies approved by the ITU
IMT-2000	The third-generation component of IMT

interference	Unwanted signals from one radio system that leak into the receivers of another system, degrading their performance
ITU	The International Telecommunications Union, a UN body that sets international, treaty-bound spectrum designations
LTE	A radio technology developed as successor to WCDMA and HSPA that supports higher data rates through higher spectrum efficiency and wider channel bandwidths
UMTS	Universal Mobile Telecommunications System — the European name for 3G
WCDMA	Wideband Code Division Multiple Access — the technology used for UMTS
Wi-Fi	A wireless networking technology that uses radio waves to provide wireless high-speed internet and network connections (Wireless local area networks or WLANs)



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