

RECOMMENDATION ITU-R M.1645

**Framework and overall objectives of the future development
of IMT-2000 and systems beyond IMT-2000**

(Question ITU-R 229/8)

(2003)

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1 Introduction

International Mobile Telecommunications-2000 (IMT-2000) systems are third generation mobile systems, which provide access to a wide range of telecommunication services, supported by the fixed telecommunication networks (e.g. PSTN/ISDN/IP), and to other services which are specific to mobile users.

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 suitable for worldwide use;
- worldwide roaming capability;
- capability for multimedia applications within a wide range of services and terminals.

The capabilities of IMT-2000 systems are being continuously enhanced in line with user demand and expectations and technology trends.

The specifications for the initial releases of IMT-2000, which are defined in Recommendation ITU-R M.1457, have been completed, and the commercial deployment of IMT-2000 has begun. Work is already under way in various external organizations to extend the capabilities of the initial releases in line with user expectations and technology trends.

To help meet the ever increasing demands for wireless communication, and the expected higher data rates needed to meet user demands, the ITU Radiocommunication Assembly approved Question ITU-R 229/8 on the future development of IMT-2000 and systems beyond IMT-2000. That Question asks generally about the overall objectives and the technical, operational and spectrum issues related to the future development of IMT-2000 and systems beyond IMT-2000. One of the initial steps in the process of addressing this Question is producing this Recommendation on the framework of the future development of IMT-2000 and systems beyond IMT-2000. Additional Recommendations and Reports will be developed to address specific issues in more detail.

2 Scope

This Recommendation defines the framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000 for the radio access network. This framework is based on the global user and technology trends, including the needs of developing countries. The Recommendation recommends the framework and objectives of the future development of IMT-2000 and systems beyond IMT-2000, specifically addressing:

- evolutionary development of IMT-2000, which refers to the enhancements of its technical capabilities, range of available services and breadth of applications that will be progressively introduced during its lifetime;
- systems beyond IMT-2000, for which there may be a need for a new wireless access technology to be developed around the year 2010, capable of supporting high data rates with high mobility, which could be widely deployed around the year 2015 in some countries.

The complete ITU framework for the future development of IMT-2000 and systems beyond IMT-2000 encompasses both the “radio access network” and the “core network”. However, it is recognized that, in the future, the evolution of technologies and the redistribution of traditional functions between radio access networks and core networks in real systems may blur this distinction. The scope of this ITU-R Recommendation is the radio access network, while the core network is addressed in a companion ITU-T Recommendation ITU-T Q.1702. The framework for the future development of the IMT-2000 and systems beyond IMT-2000 radio access networks includes the emerging relationships with other radio access networks (existing and future), and the capabilities required to deliver services to the users of IMT-2000 and systems beyond IMT-2000.

3 Related Recommendations

ITU-R F.1399	Vocabulary of terms for wireless access
ITU-R M.687	International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.816	Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.818	Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.819	International Mobile Telecommunications-2000 (IMT-2000) for developing countries

ITU-R M.1034	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.1035	Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.1182	Integration of terrestrial and satellite mobile communication systems
ITU-R M.1224	Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R M.1311	Framework for modularity and radio commonality within IMT-2000
ITU-R M.1450	Characteristics of broadband radio local area networks
ITU-R M.1457	Detailed specification of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
ITU-T Q.1702	Long-term Vision of Network Aspects for Systems Beyond IMT-2000

4 Considerations

The ITU Radiocommunication Assembly,

considering

4.1 User trends

In defining the framework for the future development of IMT-2000 and systems beyond IMT-2000, it is important to understand the user trends that will affect the development of such systems. In particular, the framework should be based on increasing user expectations and the growing demand for mobile services, as well as the evolving nature of the services and applications that may become available. The trends discussed below are thus an important underpinning of the framework.

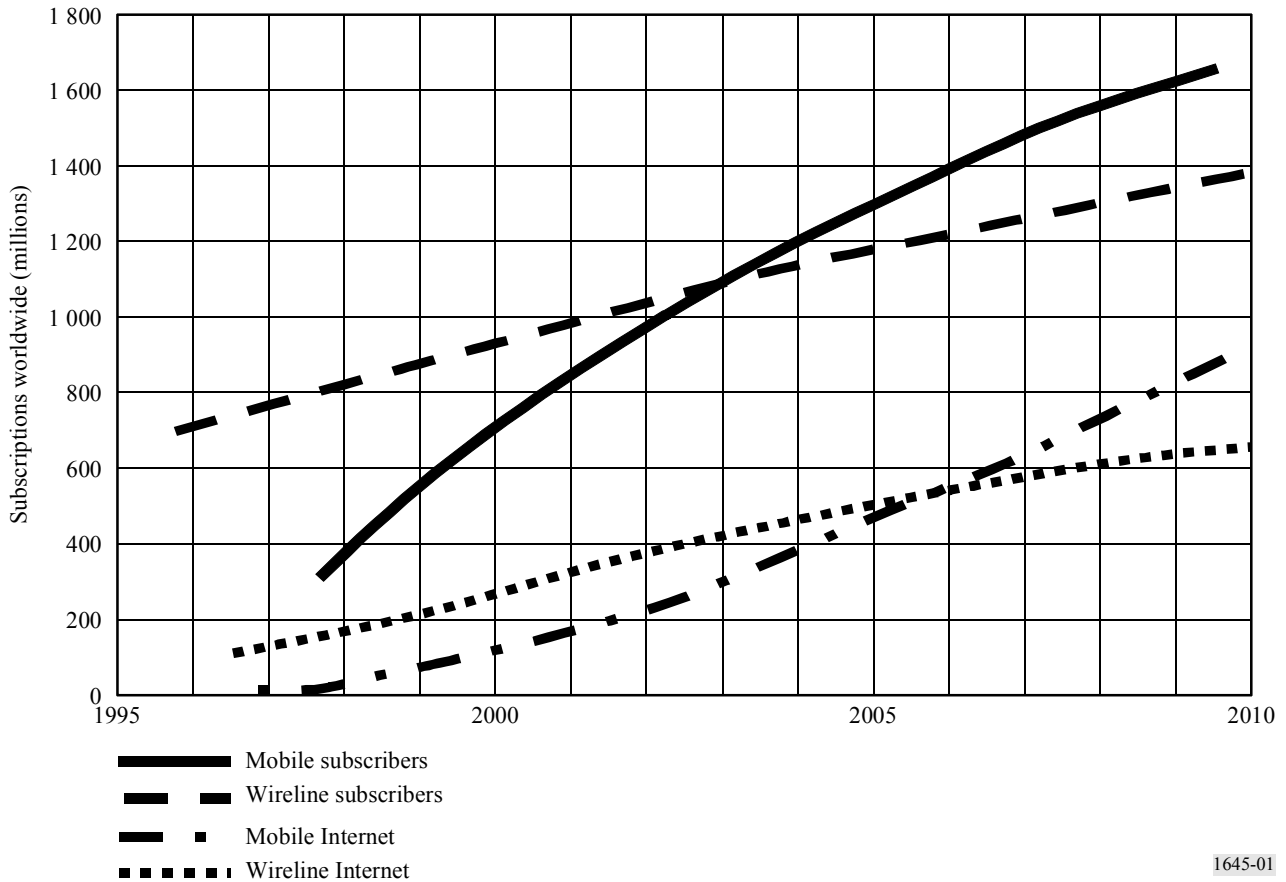
4.1.1 Growing demand for mobile services

The number of mobile subscribers worldwide has increased from 215 million in 1997 to 946 million (15.5% of global population) in 2001 as shown in Fig. 1¹. It is predicted that by the year 2010 there will be 1 700 million terrestrial mobile subscribers worldwide. A substantial portion of these additional subscribers are expected to be from outside the countries that already had substantial numbers of mobile users by the year 2001.

It is envisaged that, by the year 2020, potentially the whole population of the world could have access to advanced mobile communications devices, subject to, amongst other considerations, favourable cost structures being achieved. There are already more portable handsets than either fixed line telephones or fixed line equipment such as PCs that can access the Internet, and the number of mobile devices is expected to continue to grow more rapidly than fixed line devices. Mobile terminals will be the most commonly used devices for accessing and exchanging information.

¹ www.itu.int/ITU-D/ict/statistics.

FIGURE 1
Global growth of mobile and wireline subscribers



4.1.2 Trends in services and applications

User expectations are continually increasing with regard to the variety of services and applications. In particular, users will expect a dynamic, continuing stream of new applications, capabilities and services that are ubiquitous and available across a range of devices using a single subscription and a single identity (number or address). Versatile communication systems offering customized and ubiquitous services based on diverse individual needs will require flexibility in the technology in order to satisfy multiple demands simultaneously.

Multimedia traffic is increasing far more rapidly than speech, and will increasingly dominate traffic flows. There will be a corresponding change from predominantly circuit-switched to packet-based delivery. This change will provide the user with the ability to more efficiently receive multimedia services, including e-mail, file transfers, messaging and distribution services. These services can be either symmetrical or asymmetrical, and real-time or non real-time. They can consume high bandwidths, resulting in higher data rate requirements in the future.

External market studies have predicted that in Europe in the year 2010 more than 90 million mobile subscribers will use mobile multimedia services, generating about 60% of the traffic in terms of transmitted bits.

In Japan, mobile web browsing, which is one type of mobile multimedia service, started to become popular around the year 2000; the number of users was 48.5 million (72% of mobile subscribers) at the end of the year 2001 and is still growing.

Work has already begun on the convergence of telecommunication services such as digital broadcasting and commercial wireless services. The trend toward integration and convergence can be characterized by:

- connectivity (provision of a pipe, including intelligence in the network and the terminal);
- content (information, including push and pull services);
- commerce (transactions).

These trends may be viewed as the integration and convergence of information technology, telecommunications, and content. This will result in new service delivery dynamics and a new paradigm in telecommunications where value added services, such as those which are location dependent, will provide enormous benefits to both the end users and the service providers.

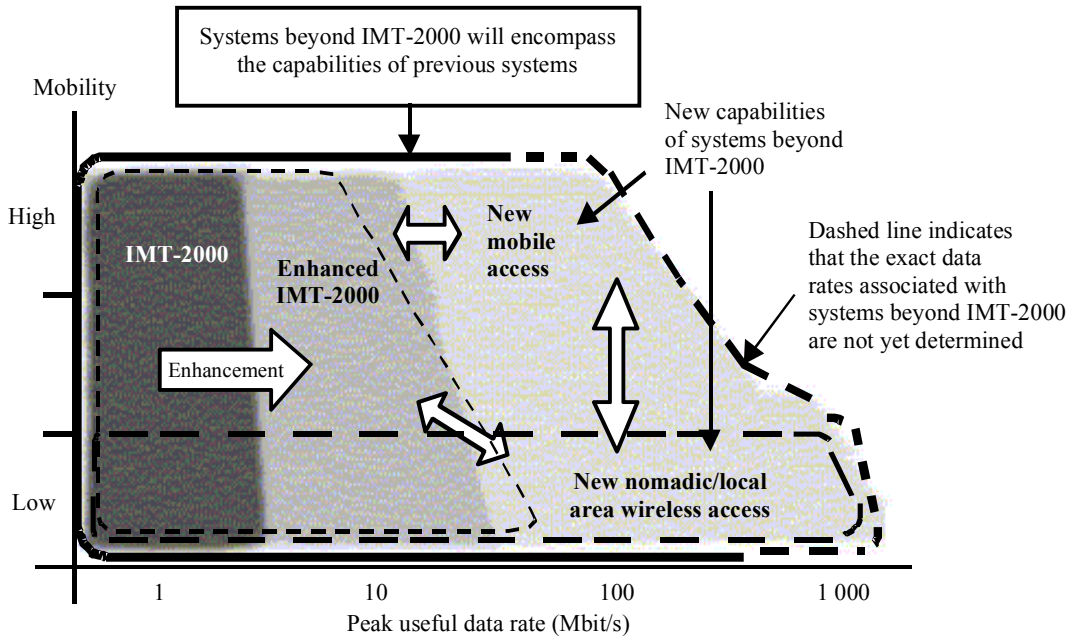
In addition, these trends are supported by “digitalization”, which is already well advanced. The majority of electronic and communications devices and delivery mechanisms (i.e. cellular, broadcast, fixed wireless access (FWA), radio local area networks (RLANs), xDSL (digital subscriber line delivery mechanisms), satellite, etc.) are either already digital or in the process of migrating to digital technologies.

4.2 Framework

Present mobile communication systems have evolved by adding more and more system capabilities and enhancements, and the user will see a significant increase in capability through the future development of IMT-2000. Systems beyond IMT-2000 will be realized by functional fusion of existing, enhanced and newly developed elements of IMT-2000, nomadic wireless access systems and other wireless systems with high commonality and seamless interworking.

The framework for the future development of IMT-2000 and systems beyond IMT-2000 is depicted in Fig. 2, which illustrates the various components described in § 4.2.1 and their relationships to each other. Systems beyond IMT-2000 will encompass the capabilities of previous systems. Other communication relationships will also emerge, in addition to person to person, such as machine-to-machine, machine-to-person and person-to-machine.

FIGURE 2
Illustration of capabilities of IMT-2000 and systems beyond IMT-2000



↔ Denotes interconnection between systems via networks, which allows flexible use in any environment without making users aware of constituent systems

○ Nomadic/local area access systems

⊖ Digital broadcast systems

Dark shading indicates existing capabilities, medium shading indicates enhancements to IMT-2000, and the lighter shading indicates new capabilities of systems beyond IMT-2000.

The degree of mobility as used in this Figure is described as follows: low mobility covers pedestrian speed, and high mobility covers high speed on highways or fast trains (60 km/h to ~250 km/h, or more).

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4.2.1 Objectives

The objectives of the future development of IMT-2000 and systems beyond IMT-2000 is considered to be as follows:

– *Future development of IMT-2000:*

There will be a steady and continuous evolution of IMT-2000 to support new applications, products and services. For example, the capabilities of some of the IMT-2000 terrestrial radio interfaces are already being extended up to 10 Mbit/s and it is anticipated that these will be extended even further up to approximately 30 Mbit/s by around the year 2005, under optimum signal and traffic conditions. This is discussed in more detail in § 4.2.4.

– *New capabilities of systems beyond IMT-2000:*

For systems beyond IMT-2000, there may be a requirement for a new wireless access technology for the terrestrial component, around the year 2010. This will complement the enhanced IMT-2000 systems and the other radio systems. It is predicted that potential new radio interface(s) will need to support data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, by around the year 2010. This is discussed in more detail in § 4.2.5.

These data rate figures and the relationship to the degree of mobility (Fig. 2) should be seen as targets for research and investigation of the basic technologies necessary to implement the framework. Future system specifications and designs will be based on the results of the research and investigations. Due to the predicted data rate requirements, additional spectrum will be needed in order to deliver the new capabilities of systems beyond IMT-2000. The data rate figures anticipate the advances in technology, and these values are expected to be technologically feasible in the time-frame noted above. It is possible that upstream and downstream may have different maximum transmission speeds.

– *Relationship of IMT-2000, systems beyond IMT-2000, and other access systems:*

In conjunction with the future development of IMT-2000 and systems beyond IMT-2000, relationships will continue to develop between different radio access and communications systems, for example wireless personal area networks (WPANs), LANs (WLANs), digital broadcast, and FWA. This is discussed in more detail in § 4.2.6.

4.2.2 Perspectives on the objectives

The framework for the future development of IMT-2000 and systems beyond IMT-2000 can be considered from multiple perspectives, including the users, manufacturers, application developers, network operators, and service and content providers. From the user's perspective, there will be a demand for a variety of services, content and applications whose capabilities will increase over time. Similarly, users will expect services to be ubiquitously available through a variety of delivery mechanisms and service providers, using a wide variety of devices that will be developed to meet their differing requirements. These may resemble today's devices such as desktop and laptop PCs, mobile phones, digital televisions, and other computing and communication devices. User demands will be addressed by a large community including content providers, service providers, network operators, manufacturers, application and hardware developers.

The objectives, as seen from various perspectives can be summarized as in Table 1:

TABLE 1
Objectives from multiple perspectives

Perspective	Objectives
END USER	<ul style="list-style-type: none"> 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
CONTENT PROVIDER	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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 (sharing of mobile, UMTS subscriber identity module (USIM), network elements, radio sites) Single authentication (independent of the access network) Flexible billing capabilities Access type selection optimizing service delivery
MANUFACTURER/ APPLICATION DEVELOPER	<ul style="list-style-type: none"> 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

4.2.3 Coverage objectives

An objective of IMT-2000, defined in Recommendation ITU-R M.687, is to make a wide range of telecommunication services available to mobile users, and to provide these services over a wide range of teledensities (number of users per square kilometre) and geographic coverage areas. This continues to be a priority for the future development of IMT-2000 and systems beyond IMT-2000. Geographic coverage is especially important to developing countries because many people who do not at present have access to mobile communications live in parts of the world where the population density, teledensity, and/or income levels are low.

Satellite networks can provide services to wide areas in sparsely populated regions, such as rural and desert zones, maritime and aeronautical environments. From this point of view, satellite networks may provide a useful complement to the terrestrial networks.

Global economies of scale will help to lower entry costs, and thus help to bring telecommunications to people who do not presently have mobile or fixed line telephones. To achieve this goal, limited system complexity is beneficial.

Geographical coverage could be increased for the terrestrial component by also using lower frequency ranges than those today identified for IMT-2000, or by using the satellite component of IMT-2000, subject to market conditions and certain limitations, such as handset size, power consumption and indoor coverage. IMT-2000 services can best be provided at low cost to rural areas and to low-income populations by using globally harmonized frequencies to minimize terminal complexity and maximize economies of scale in order to minimize system cost.

To meet users' expectations, it is important that the service area of IMT-2000 networks is maintained for systems beyond IMT-2000 where needed, taking into account the effects of higher bit rate, operating frequency and advances in technology.

4.2.4 Future development of IMT-2000

The capabilities of IMT-2000 will continue to steadily evolve over at least the next ten years as IMT-2000 technologies are upgraded and deployed. From a radio access perspective, it is expected that the future development of IMT-2000 will build on and further develop the radio access systems and technologies already being developed and deployed. This would be followed by further operation for possibly a further ten years or more. This evolution will enhance stability and promote the development of an expanding number of services and applications.

Similarity of services and applications across the different IMT-2000 technologies and frequency bands is beneficial to users, and a broadly similar user experience leads to a large-scale take-up of products and services, common applications and content, and an ease and efficiency of use.

Terrestrial IMT-2000 systems are already being enhanced (for instance, towards IP-based network and to offer bit rates up to 10 Mbit/s under favourable circumstances). These initial enhancements, for which standards are already being developed, will be followed by further enhancements that could increase the peak aggregate useful data rate up to approximately 30 Mbit/s under favourable

circumstances by around 2005; however, some operators may need additional spectrum to realize these enhancements.

The satellite component of IMT-2000 may further evolve to provide complementary services (e.g. broadcasting, multicasting).

Today mobile-satellite services are mainly used in areas where there is no terrestrial mobile network. The future development of the satellite component of IMT-2000 is envisaged to complement future IMT-2000 networks, and is intended to provide higher data rates and new services (compared to today's satellite systems), in particular to individuals or devices that are outside the coverage of the terrestrial network.

4.2.5 New capabilities for systems beyond IMT-2000

The services that users will want, and the rising number of users, will place increasing demands on access networks. These demands may eventually not be met by the enhancement of IMT-2000 radio access systems (in terms of peak bit rate to a user, aggregate throughput, and greater flexibility to support many different types of service simultaneously). It is therefore anticipated that there will be a requirement for a new radio access technology or technologies at some point in the future to satisfy the anticipated demands for higher bandwidth services.

This Recommendation provides a very high-level view of the framework for the new capabilities envisaged for systems beyond IMT-2000, and the new radio interface(s) that might be needed to support them. Further ITU-R Recommendations will develop these concepts in more detail. Other new Recommendations will address spectrum requirements for systems beyond IMT-2000, which frequency bands might be suitable, and in what time-frame such spectrum would be needed, with a view to accommodating emerging broadband services and applications. It is expected that new spectrum requirements documented in these Recommendations will be addressed at a future World Radiocommunication Conference. This topic is included in Resolution 802 (WRC-03) as agenda item 1.4 for WRC-07.

Systems beyond IMT-2000 will support a wide range of symmetrical, asymmetrical, and unidirectional services. They will also provide management of different quality of service levels to realize the underlying objective of efficient transport of packet-based services. In parallel, there will be an increased penetration of nomadic and mobile wireless access multimedia services.

The technologies, applications and services associated with systems beyond IMT-2000 could well be radically different from the present, challenging the perceptions of what may be considered viable by today's standards and going beyond what can be achieved by the future enhancement of IMT-2000 working with other radio systems.

The new radio access interface(s) are envisaged to handle a wide range of supported data rates according to economic and service demands in multi-user environments with target peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access (Fig. 2). These data rates are targets for research and investigation. They should not be taken as the definitive requirements for systems beyond IMT-2000.

These data rates will be shared between active users. The achievable (peak or sustained) throughput for any individual user depends on many parameters, including the number of active users, traffic characteristics, service parameters, deployment scenarios, spectrum availability, and propagation and interference conditions. These data rates are the maximum value of the sum of the data rate for all of the active users on a radio resource; it is possible that the peak data rate needed in the upstream direction will be different from the downstream direction. The transport data rates may need to be higher due to overheads, such as signalling and coding. Depending on the services for which the technology(ies) will be used, continuous radio coverage may not be needed in order to meet the service requirements.

4.2.6 Relationship of IMT-2000, systems beyond IMT-2000 and other access systems

Wireless communications comprises a wide range of technologies, services and applications that have come into existence to meet the particular needs of different deployments and user environments. Different systems can be broadly characterized by:

- content and services offered;
- frequency bands of operation;
- standards defining the systems;
- data rates supported;
- bidirectional and unidirectional delivery mechanisms;
- degree of mobility;
- regulatory requirements;
- cost.

Second generation systems were mainly designed for applications such as voice. IMT-2000 and enhanced IMT-2000 systems and systems beyond IMT-2000 will increasingly be designed as combination of different access technologies to complement each other in an optimum way for different service requirements and radio environments in order to provide a common and flexible service platform for different services and applications.

A similarity of services and applications across the different systems is beneficial to users, and this has stimulated the current trend towards convergence. Furthermore, a broadly similar user experience across the different systems leads to a large-scale take-up of products and services, common applications and content and an ease and efficiency of use. However, such convergence should not preclude opportunities for competitive innovation. Access to a service or an application may be performed using one system or may be performed using multiple systems simultaneously (e.g. a digital broadcast channel and a return channel using IMT-2000).

The increasing prevalence of IP-based applications is a key driver for this convergence and facilitates the establishment of relationships between previously separate wireless platforms. What form these relationships will take depends on user requirements, but they might include, for example, hardware integration within a device, network interworking, common access,

authentication, accounting, common man-machine interfaces, portals, roaming and handover between systems.

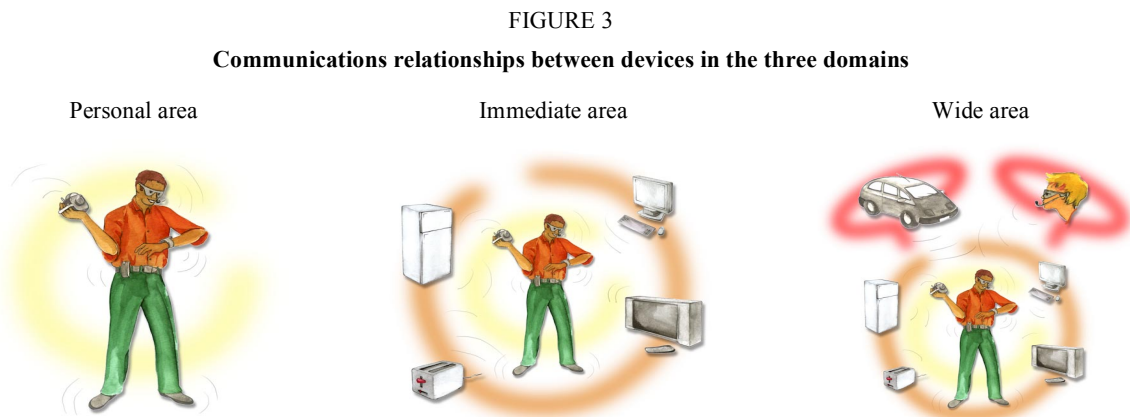
An individual person, or machine, might from time to time be a user on one or more of these systems, either sequentially or simultaneously, depending on the task at hand.

The formation of these relationships is distinct from the development of each wireless access system, including IMT-2000; it will need to take into account the characteristics and future development of the systems, interrelated (or even interdependent) spectrum issues and the respective regulatory environments.

The relationships between and among systems and devices can be broadly described as follows:

- *The personal area domain:* This consists of communications between terminal and peripheral devices that move with the user and communicate directly with each other (e.g. communication between headset and mobile terminal).
- *The immediate area domain:* This comprises direct communication between a user device and other devices (e.g. communication of a refrigerator, digital television, home gateway, etc.) in the immediate environment of the user. This communication covers a maximum range of a few metres up to several tens of metres.
- *The wide area domain:* This comprises the communication of devices via the infrastructure of network operators. One example is the communication between mobile terminals and servers in the network.

These three domains are illustrated in Fig. 3.



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It is important to note that different technologies, such as RLAN, short range connectivity systems, and IMT-2000, may be present in a single device operating across various networks at any particular time. For example, a personal digital assistant may contain multiple radio interfaces enabling it to communicate with a mobile terminal (personal area domain); a private or public RLAN (immediate area domain); or a wide-area service provider, such as a mobile (cellular) network (wide area domain).

From a service provision perspective, the domains share some common characteristics. Wireless service provision will be characterized by global mobile access (terminal and personal mobility), high security, high service quality and ergonomic access to personalized multimedia services for

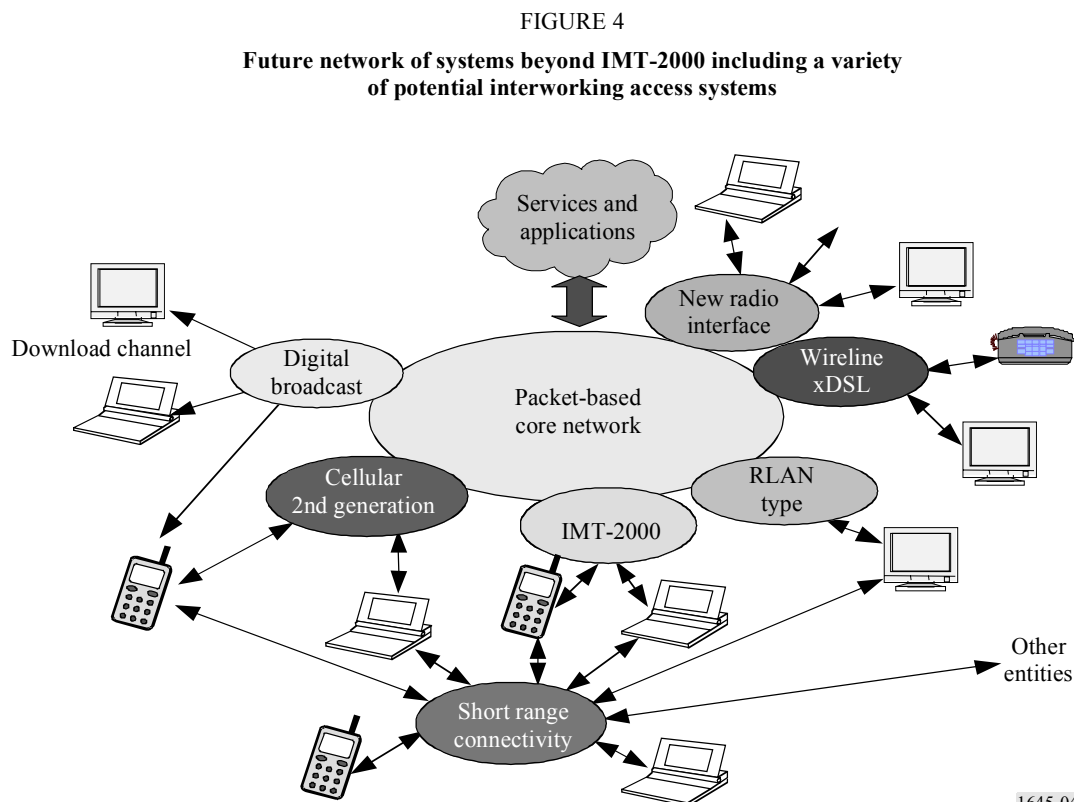
voice, data, message, video, World Wide Web, and location-based services via one or multiple user terminal(s).

One important element in realizing this framework of integrated services, given the emerging dominant role of packet-based applications and networks, is the development of suitable adaptive packet data transfer solutions. It should be possible to support asymmetric traffic in an efficient way.

In the future operators may deploy a mix of technologies that could, at various stages in time, and subject to market and regulatory considerations, incorporate cellular, RLAN, digital broadcast, satellite and other access systems. This will require the seamless interaction of these systems in order for the user to be able to receive a variety of content via a variety of delivery mechanisms depending upon the particular terminal capabilities, location and user profile.

Different radio access systems will be connected via flexible core networks. In this way, an individual user can be connected via a variety of different access systems to the networks and services he desires. The interworking between these different access systems in terms of horizontal and vertical handover and seamless service provision with service negotiation including mobility, security and QoS management will be a key requirement, which may be handled in the core network or by suitable servers accessed via the core network.

This “optimally connected anywhere, anytime” view could be realized by a network comprising a variety of interworking access systems connected to a common packet-based core network, as seen in Fig. 4.

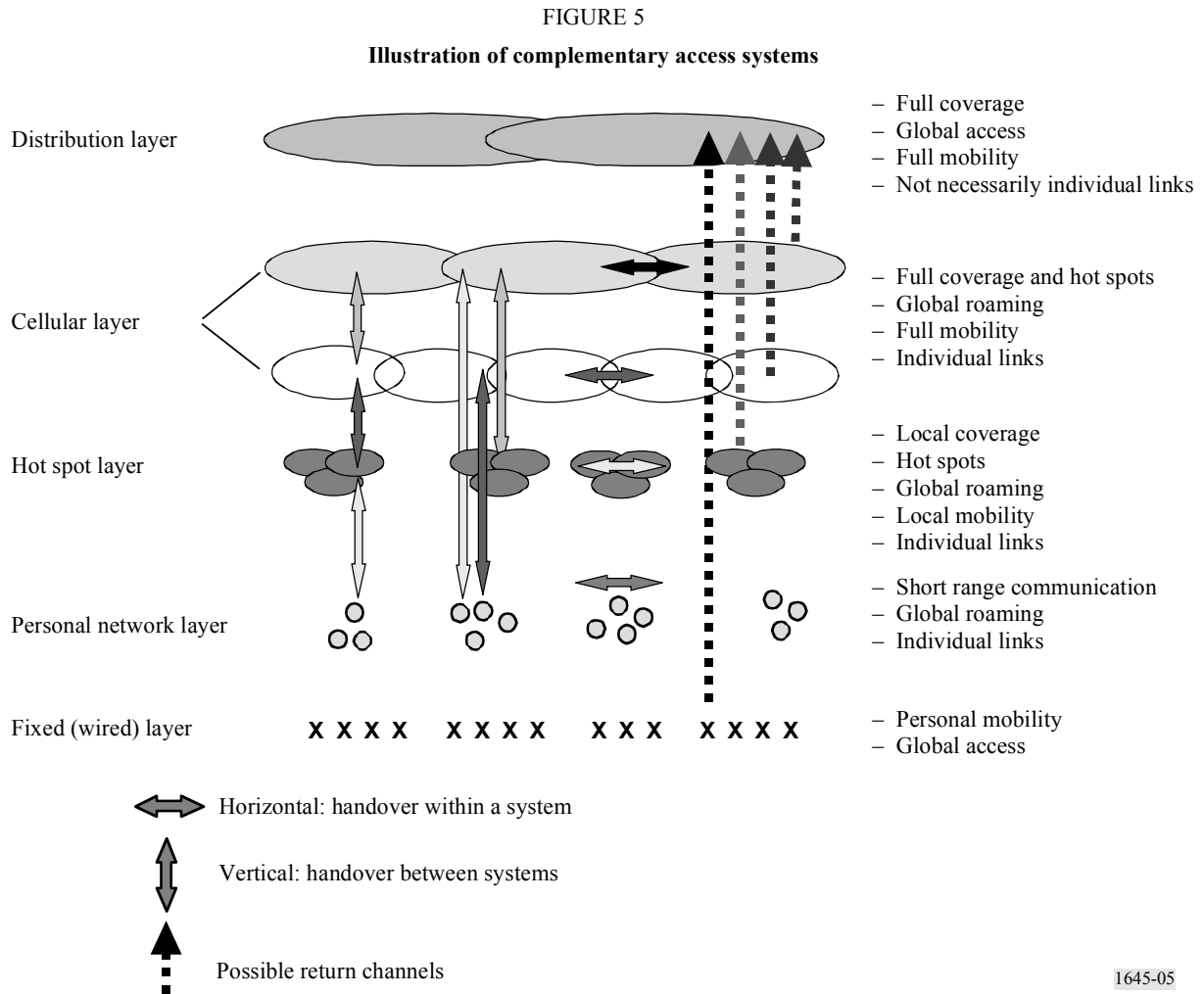


Due to the different application areas, cell ranges and radio environments, the different access systems can be organized in a layered structure (according to Fig. 5) similar to hierarchical cell structures in cellular mobile radio systems. This allows deployment of the necessary system capacity and capability where needed. Figure 5 presents an illustration of examples of the seamless interworking between different complementary access systems in a deployment area. Interworking between different access systems will be performed in terms of vertical handover or session continuation including service negotiation to adapt the application to the service capabilities of the candidate access systems (double-sided arrows). The single-ended arrows correspond to return channels for broadcast type channels. The different layers correspond to the:

- *distribution layer*: this layer comprises digital broadcast type systems to distribute the same information to many users simultaneously through unidirectional links. Other access systems can be used as a return channel;
- *cellular layer*: the cellular layer may comprise several cell layers with different cell size and or different access technologies;
- *hot spot layer*: this layer may be used for very high data rate applications, very high traffic density and individual links, e.g. in very dense urban areas, campus areas, conference centres, and airports;
- *personal network layer*: personal area networks will support short-range direct communication between devices;
- *fixed (wired) layer*: this layer includes any fixed wireline access system.

The enhanced IMT-2000 and the new mobile access of systems beyond IMT-2000 will be part of the cellular layer and hot spot layer. Nomadic/local wireless access of systems beyond IMT-2000 will be part of the hot spot layer.

Figure 5 illustrates a flexible and scalable environment which can be used for the allocation of system capacity in a deployment area, where one or several systems may be deployed according to need.



4.2.7 Timelines

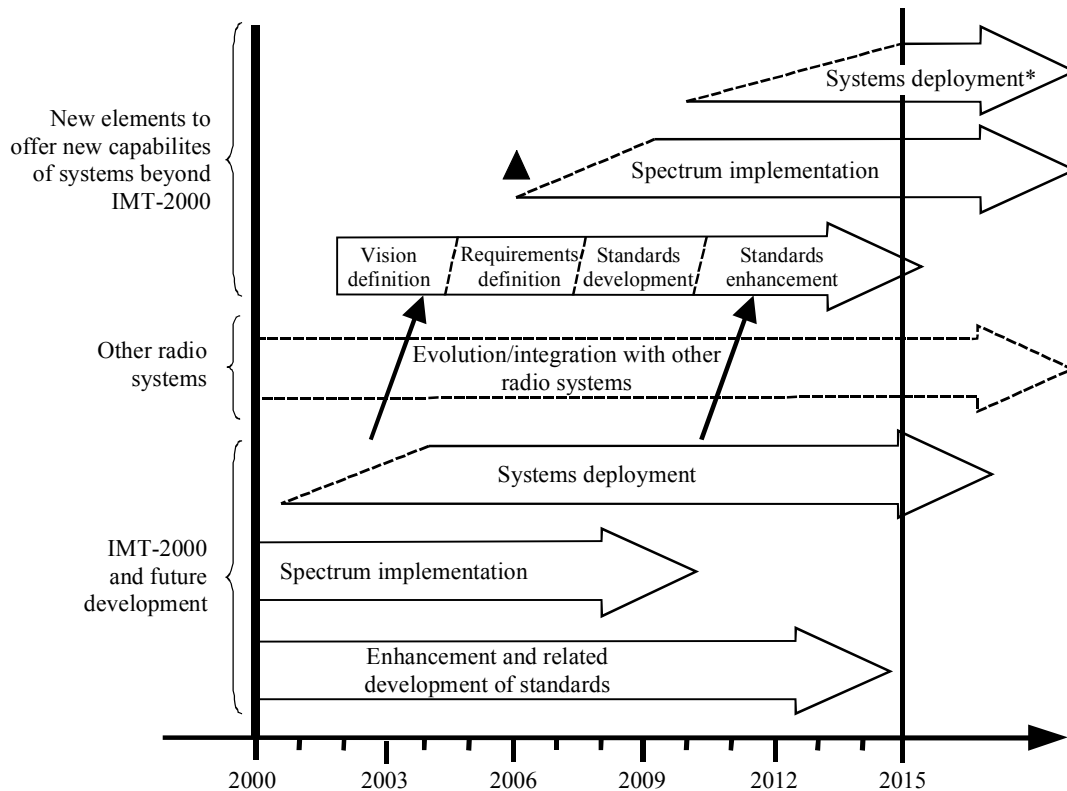
In planning for the future development of IMT-2000 and systems beyond IMT-2000, it is important to consider the timelines associated with their realization, which depend on a number of factors:

- user trends, requirements and user demand;
- technical capabilities and technology developments;
- standards development;
- spectrum availability, including allowing sufficient time to re-locate systems that may be using proposed bands;
- regulatory considerations;
- system (mobile and infrastructure) development and deployment.

All of these factors are interrelated. The first five have been and will continue to be addressed within ITU. System development and deployment relates to the practical aspects of deploying new networks, taking into account the need to minimize additional infrastructure investment and to allow time for customer adoption of the services of a major new system, such as IMT-2000.

The timelines associated with these different factors are depicted in Fig. 6. When discussing the time phases for systems beyond IMT-2000, it is important to specify the time at which the standards are completed, when spectrum must be available, and when deployment may start.

FIGURE 6
Phases and expected timelines for future development of IMT-2000 and systems beyond IMT-2000



The sloped dotted lines indicate that the exact starting point of the particular subject can not yet be fixed.

▲ : Possible spectrum identification at WRC-07

* : Possible wide deployment around the year 2015 in some countries

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4.2.7.1 Medium term

In the medium-term (up to about the year 2010) it is envisaged that the future development of IMT-2000 will progress with the ongoing enhancement of the capabilities of the initial deployments, as demanded by the marketplace in addressing user needs and allowed by the status of technical developments. This phase will be dominated by the growth in traffic within the existing IMT-2000 spectrum, and the development of IMT-2000 during this time will be distinguished by incremental or evolutionary changes to the existing IMT-2000 radio interface specifications (i.e. these changes can be reflected in revisions to existing IMT-2000 ITU-R M-series Recommendations). There could be significant progress towards harmonization of the radio interfaces and the introduction of packet-based core networks.

It is envisaged that the bands identified by WRC-2000 will be made available for IMT-2000 within this time-frame, subject to user demand and other considerations.

4.2.7.2 Long term

The long term (beginning around the year 2010) is associated with the potential introduction of new radio interface(s) which could be widely deployed around the year 2015 in some countries and with capabilities significantly beyond those envisaged for IMT-2000 as it evolves during the medium term. It is envisaged that the new interface(s) will add significant new capabilities (e.g. much higher user data rates), and they may need additional frequency bands in which to operate. Evolutions in technologies, interworking between frequency bands and different access systems and improvement in spectrum efficiency may reduce the amount of additional spectrum needed. It is anticipated that certain core capabilities will be common to both enhanced IMT-2000 and systems beyond IMT-2000.

It is currently envisaged that the new radio interface(s) of systems beyond IMT-2000 will be primarily and initially intended for use in new spectrum identified by future WRCs.

4.3 Technology trends

In defining the framework and objectives for the future development of IMT-2000 and systems beyond IMT-2000, the significant technology trends need to be considered. This section identifies the technology domains in which trends can be foreseen at the time of preparation of this Recommendation. Depending on their development, evolution, realized capabilities and cost structure, each of these technology trends may or may not have an impact or be used for the systems beyond IMT-2000. It is expected that the research and development of systems beyond IMT-2000 will consider these trends and provide guidance on the applicability or influence they might have on systems beyond IMT-2000. The technology trends will be described in more detail in a separate Report.

4.3.1 System-related technologies

With respect to requirements on high data rates and high mobility, new or evolved architectures are foreseen, in particular those related to the use of packet-based architectures which will offer increased system security and reliability, intersystem mobility and interoperability capabilities.

Example key technologies:

Voice over IP; optimization of IP for mobile radio transmission; fault-tolerant (high reliability) network architecture; seamless mobility, (inter-system handover, roaming, optimal network selection); mobile platform technology; security and privacy; cryptography; authentication and mobile electronic commerce; billing; intelligent data filtering.

4.3.2 Access network and radio interface

New concepts and radio access techniques may influence the future development of IMT-2000 and systems beyond IMT-2000. These include, but are not limited to:

- modulation and coding schemes;
- multiple access schemes;
- software defined radio and reconfigurable systems;

- adaptive radio interface;
- new antenna concepts and technologies.

Example key technologies:

Software defined radio; novel access network architectures (e.g. high packet rate nodes); mobile ad hoc networks; routing algorithms; multicast; radio over fibre; handover between different radio interfaces (vertical and horizontal); dynamic QoS control; packet mobility control; robust packet transmission; distributed MAC; error correction and channel coding; adaptive and higher order modulation and link adaptation; adaptive antennas; MIMO (Multiple Input Multiple Output); multi-user detection and interference cancellation; backhaul links.

4.3.3 Utilization of spectrum

New techniques to increase spectrum utilization and spectrum efficiency, and to allow spectrum resources to be shared between users, are being studied. These studies may lead to improved frequency usage and/or to new ways to share the spectrum resource with other users or systems.

Example key technologies:

Hierarchical cell structures (including three dimensional); adaptive antennas; MIMO; adaptive dynamic channel assignment; spectrum sharing (between different operators and systems).

4.3.4 Mobile terminals

Major evolutions are foreseen in mobile terminals, with use of new components, new architectures, new hardware and software platforms, and improved user interfaces, which will together provide increased performance.

Example key technologies:

Man-machine interfaces (including “intelligent” mobile terminals); integration of mobile terminals and IT devices; mobile terminal platforms (operating systems, middlewares and application programming interfaces); autonomous subsystem architecture (separate communication and applications subsystems); advances in display devices; voice recognition; wearable terminals; software defined radio and multi-mode terminals; advances in processing power of semiconductors (as described by Moore’s Law); improvements in RF devices (allowing higher operating frequencies and improved receiver sensitivity); RF MEMS (micro electro-mechanical systems); battery technology (increased energy density).

4.3.5 Applications

Applications accessed through IMT-2000 and systems beyond IMT-2000 will evolve:

- to follow the general trends of telecommunication systems;
- to adapt to the capabilities of the mobile systems and optimize service delivery in the radio environment.

Example key technologies:

Data coding and compression techniques; dynamic variable-rate codecs; mobile agents; content description language; streaming of speech and video; APIs (application programming interfaces) and middlewares.

4.4 Spectrum implications

A critical consideration in realizing the framework for the future development of IMT-2000 and systems beyond IMT-2000 is the availability of adequate spectrum to support future services. When considering the requirements and potential frequency ranges to support these systems, it is useful to consider the timelines, services and technology trends discussed above, recognizing that these topics may be further developed in additional Recommendations and Reports. More specifically, in analysing the spectrum implications of the future development of IMT-2000 and systems beyond IMT-2000, many issues must be addressed, including, but not limited to:

- traffic projections and requirements including ratio of asymmetry;
- service and application requirements;
- spectrum efficiency;
- radio transmission characteristics (time division duplex (TDD)/frequency division duplex (FDD), duplex direction, transmit/receive separation, modulation and access schemes, etc.);
- global roaming requirements and harmonized use of spectrum;
- technical solutions to facilitate global roaming;
- techniques of dynamic spectrum sharing;
- sharing and compatibility analysis;
- evolution of IMT-2000 systems.

With the ongoing growth in number in mobile users and the anticipated growth of data applications and bandwidth, additional spectrum may be needed. However, technology advances will allow a more efficient use of spectrum. For the determination of any additional spectrum, new analysis will be needed. This new analysis should take into account the advances in technology, traffic models and user demands. All efforts will be made to use the spectrum as efficiently as possible to limit the additional spectrum demand. The analysis must also consider the constraints associated with realizing the data rate targets, including potential availability of spectrum in suitable frequency ranges. The necessary methodology for calculation and estimations on the expected spectrum demand will be addressed in other ITU-R Recommendations.

Figure 2 illustrates the capabilities of IMT-2000 and systems beyond IMT-2000. This Recommendation only considers the spectrum implications for the new capabilities for systems beyond IMT-2000 illustrated in Fig. 2.

The spectrum demand is determined by the data rate targets, the modulation, coding, etc. methods (physical layer), advanced antenna concepts, guardbands, frequency bands, deployment conditions, among others. The necessary steps in calculating this spectrum demand include:

- to develop a method for calculation of the spectrum demand;
- the assessment of potential new technologies for efficient use of the spectrum; and
- the investigation of new methods for reuse and sharing of spectrum.

4.4.1 Preferred frequency bands

It is expected that IMT-2000 and its enhancements will continue to operate in the bands identified by WARC-92 and WRC-2000. To fulfil the framework for systems beyond IMT-2000, it is envisaged that further spectrum may be needed in addition to that identified for IMT-2000 at WARC-92 and WRC-2000. The new capabilities for mobile access and nomadic/local wireless access have different objectives for mobility and bit rate, for which different frequency ranges may be appropriate.

For the new mobile access capability, data rates higher than IMT-2000 would result in a smaller cell size. The cell size also decreases at higher frequencies. This would increase the number of base stations required and hence the deployment cost. It would therefore be preferable for the frequency bands that support the wide area mobility capability of systems beyond IMT-2000 to be reasonably close to the bands already identified for IMT-2000. Since it is becoming increasingly difficult to find suitable spectrum for new applications, especially if a wide bandwidth or paired spectrum is needed, it is necessary to identify the spectrum at an early stage so that it can be made available for use in a timely manner.

Internationally agreed frequency bands will encourage the adoption of systems beyond IMT-2000 by facilitating global roaming and reducing equipment cost through global economies of scale. Common global spectrum is a preferred objective.

4.4.2 Bandwidth considerations

To fulfil the framework of systems beyond IMT-2000, sufficient spectrum should be available both for the launch of services and, later, to carry the predicted traffic for systems beyond IMT-2000.

The factors influencing the bandwidth needed for launch of service include:

- the RF bandwidth of a single carrier;
- reuse factor;
- duplex technique (ranging from slightly greater than one for TDD to two for symmetrical FDD);
- the number of carrier frequencies which an operator needs to operate an efficient network (taking into account technology trends, for example in hierarchical cell structures);
- the number of operators;

- an allowance for guardbands;
- whether the spectrum is segmented between network operators or “pooled” and also whether it is shared with other radio services.

The factors influencing the bandwidth needed to carry the predicted traffic include:

- traffic models and QoS requirements (including peak traffic demand, average traffic demand and allowed latency);
- duplex technique;
- the spectrum efficiency of the radio interface (including the reuse factor);
- trunking efficiency;
- technologies for spectrum reuse within a cell, such as adaptive antennas and MIMO;
- an allowance for guardbands.

It is likely that not all of the spectrum required in the longer term for systems beyond IMT-2000 will be available for the initial launch of service. It is therefore desirable that systems beyond IMT-2000 may be launched using less spectrum than that expected to be needed later to support the predicted traffic.

Spectrum will be more encumbered, less available and fully utilized. Access to bands with favourable propagation characteristics is likely to be difficult. Therefore, spectrum (as the radio natural resource) may not be used as it is today, because the efficient use of scarce frequency bands and the convergence of services may require the need for dynamic spectrum sharing. This has to be taken into account in the evolution to enhanced IMT-2000 systems and systems beyond IMT-2000.

5 Recommendations

The ITU Radiocommunication Assembly,

recommends

5.1 Objectives

- that enhanced IMT-2000 systems should support a steady and continuous evolution of new applications, products, and services through improvements in data rates and enhancements to the existing IMT-2000 radio interfaces;
- that the framework for systems beyond IMT-2000 should be realized by the functional fusion of existing, enhanced and newly developed elements of IMT-2000, nomadic wireless access systems and other wireless systems with high commonality and seamless interworking and interoperability;

- that the development of new radio interface(s) should recognize that any new wireless access technology for systems beyond IMT-2000 may be mainly used in conjunction with pre-IMT-2000, IMT-2000, and enhanced IMT-2000 wireless access technologies (as detailed in Recommendation ITU-R M.1457) and other existing radio systems;
- that the potential new radio interface(s) of systems beyond IMT-2000 should support data rates higher than enhanced IMT-2000, with either an adaptive interface or multiple interfaces with maximum commonality;
- that the services offered over the wireless access technologies comprising IMT-2000 and systems beyond IMT-2000 should appear as seamless and as common as possible from the user's perspective, taking into account the limitations of particular wireless access technologies and requirements of the user, so that the user may not need to be concerned with the underlying technology being used at a particular time or location.

5.2 Framework of future work

a) Review of user trends

- that once mobile multimedia data services have been widely deployed and sufficient user experience gained, the characteristics and trends information from such experience be considered in re-evaluating the user requirements for the future development of IMT-2000 and systems beyond IMT-2000;
- that reviews of user trends be undertaken as and when required and reflected in possible future revisions to this Recommendation.

b) Research

- that research, on a global basis, be undertaken to address the framework detailed in this Recommendation and into a potential new wireless access technique(s) for the terrestrial component;
- that a global cooperation of the various wireless research fora is encouraged;
- that work should be undertaken to enhance the interrelation between satellite and terrestrial mobile systems, particularly on seamless interworking between them;
- that research on the specifications for the future development of IMT-2000 and systems beyond IMT-2000 consider how these systems may relate to other radio technologies and systems and how all systems will continue to evolve;
- that the goals for the capability of systems beyond IMT-2000 are up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access around the year 2010. These goals are targets for research and investigation and may be further developed in other ITU Recommendations, and may be revised in the light of future studies;

- that new technologies and technology trends be studied for their possible contributions to the effective and efficient realization of the framework for the future development of IMT-2000 and systems beyond IMT-2000;
- that work should be undertaken to further improve the efficient and effective use of spectrum for the future development of IMT-2000 and systems beyond IMT-2000.

c) Spectrum

- that the need for spectrum for the future development of IMT-2000 and systems beyond IMT-2000, beyond that already identified in the Radio Regulations for IMT-2000, may be considered in time for future WRCs;
- that user demand requirements are considered when determining future potential frequency ranges;
- that the technical requirements to facilitate the cost-effective deployment of a new radio interface(s) to satisfy the new mobile access and nomadic/local wireless access capabilities are considered when determining potential frequency ranges;
- that globally common spectrum and harmonized frequency arrangements should continue to be sought for the future development of IMT-2000 and systems beyond IMT-2000.

d) Standardization

- that detailed standardization of the radio interface(s) should take into account the frequency band(s) in which it is intended to be used;
- that global and open standardization of the radio interface specifications should continue in the future to realize the benefits of mass market and ensure interoperable equipment so that users, operators, manufacturers, etc. can continue to benefit from mobile communications;
- that the level and type of standardization should be adapted to meet technical and user requirements at that time;
- that standardization should be performed in a timely manner prior to system deployment and should take into account the availability of spectrum and user considerations.

5.3 Focus areas for further study

- that research forums and other external organizations wishing to contribute to the future development of IMT-2000 and systems beyond IMT-2000, are encouraged to focus especially in the following key areas:
 - a) radio interface(s) and their interoperability;
 - b) access network related issues;
 - c) spectrum related issues;
 - d) traffic characteristics;
 - e) user estimations.

A more detailed description of the research topics is found via a hyperlink at: <http://www.itu.int/itu-r/study-groups/rsg8/rwp8f/index.asp>.