**RADIOCOMMUNICATION STUDY GROUPS**

**Document 8F/TEMP/111-E**
**26 February 2001**

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**21 – 27 February 2001, Rabat, Morocco**

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**DG Vision PDNR**[1]

UPDATED VERSION OF PRELIMINARY DRAFT NEW RECOMMENDATION (PDNR): VISION AND OBJECTIVES OF THE ONGOING ENHANCEMENT OF IMT-2000 AND OF SYSTEMS BEYOND IMT-2000

*Editor's notes, 26 Feb 2001:*

1. *This entire document should be considered as "within square brackets," i.e., it is unreviewed and unagreed in its entirety. Contributions are requested toward stabilization of the contents.*
2. *Contributors to the PDNR are reminded that the recommendations includes all sections of the body of the PDNR and all of the annexes. The attachments are informative and are not considered to be recommendations.*
3. *The agreed structure has corresponding annexes for each of the major sections; the intent is that only essential information be placed in the body of the Recommendation and that the details be placed in the corresponding Annex.*
4. *Contributors are reminded that the WP 8F Document 235 input to the 4th WP 8F Meeting contained modifications to text (additions and deletions) in addition to the structural changes. Whilst Document 235 was agreed to be the baseline structural document, the text changes contained in Document 235 were neither discussed or agreed during the 4th WP 8F Meeting. Therefore, contributors to the 5th WP 8F Meeting may which to review Document 8F/184 as well as this document. However, proposed changes should be made against the text in this version of the document. A summary of the textual changes proposed in Document 235 are provided below:*
5. *It was agreed that this version of the PDNR will serve as the baseline against which proposed changes should be submitted. Specific text in this document is not approved or agreed.*
6. *It is the intent that this PDNR be a concise technical recommendation that will be useful in determining spectrum requirements and for other uses. This document may serve as an overarching document that will generate the creation of other more detailed Recommendations (e.g., recommendations or reports on wireless IP and SDR).*

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7. *Future contributions are solicited as to whether and how the informative attachments could be reduced in the number of pages that are required.*

**Summary**

*Editor's Note: Summary should be consolidated to be as concise as possible, consideration should be given to moving some of the discussion to ~~one of~~ the Annexes.*

This Recommendation defines a vision for the ongoing enhancement of IMT-2000 systems and for systems beyond IMT-2000. A key consideration in the original IMT-2000 concept as defined by ITU-R was to provide worldwide roaming capability and to facilitate global deployment. In defining overall objectives for the ongoing enhancement of IMT-2000 and systems beyond, worldwide roaming and a global vision are again key considerations.

In defining the original IMT-2000 concept, various market studies were conducted in order to determine required capabilities for the IMT-2000 radio interfaces, services, applications and spectrum requirements. The initial consideration of services and applications envisaged from IMT-2000, subsequently documented in ITU-R M.687, focused predominantly on the provision of voice and low speed data. Market trends led to substantial revision of this vision, with the addition of multimedia capabilities and packet data services. It was apparent that these were likely to be key drivers for future mobile systems, and hence new market studies were conducted which allowed the determination of spectrum requirements for IMT-2000 up to the year 2010. This work was carried out in the lead up to WRC-2000 and is documented in Report ITU-R [IMT.SPEC].

In creating a vision for the ongoing enhancement of IMT-2000 and systems beyond, it is again appropriate to update the market forecasts in order to understand the requirements of the mobile communications customers, and hence define the extended capabilities (including the air-interface capabilities) needed from the networks. It is particularly important to establish market trends beyond the year 2010.

Furthermore, it is equally important to address the likely trends in technology developments over the timescales under review. Such an analysis will indicate the limits of what could be offered to the market at realistic cost, and thereby keep the vision within the bounds of practical realization.

This Recommendation provides a high level consideration of market developments, technology trends, system scenarios, services, applications, coverage and delivery platforms for IMT-2000 and systems beyond. This projection of the new capabilities and likely timescales will facilitate the evolution of the IMT-2000 vision and prepare the way for the systems beyond.

The Vision captures global trends, including the particular needs of the developing countries.

## 1 Background

The specifications for the initial releases of IMT-2000 have now been completed, and are defined in Recommendation ITU-R M.1457. Recommendation ITU-R M.1457 details the radio interfaces for IMT-2000. Based on this international framework, a number of countries are now embarking on the licensing of terrestrial IMT-2000 networks, and commercial deployment of IMT-2000 system is expected to begin in 2001/2002. Satellites are also in the process of being manufactured and launched, or existing satellite systems being reconfigured, so as to offer communications conforming to the satellite component of IMT-2000.

However, work is already underway to extend the capabilities of the initial releases towards fulfilment of IMT-2000 requirements that are already evolving in line with market expectations and technology trends. ITU-R WP 8F is tasked with documenting a vision of this ongoing enhancement of IMT-2000, and with the identification of a vision and some initial objectives for future systems beyond IMT-2000. There is a logical order to these tasks. The latter task will be facilitated if the development of a vision and objectives of the ongoing enhancement of IMT-2000 itself is first completed.

The purpose of this Recommendation is to define these visions and objectives. In fulfilling this task, it tries to take account of the dynamic trends in the market place, the progress of technology, and future service and application expectations in a telecommunications environment that will increasingly bring together fixed, mobile and broadcasting delivery platforms.

The Recommendation also takes into account relevant external work, and makes extensive use of appropriate references to such external work, e.g. Partnership Projects (PPs), Standards Development Organizations (SDOs), recognised external organisations, and market analysis provided by external organisations.

## 2 Scope

*Editor's Note: Clear understanding of ongoing enhancement of IMT-2000 and systems beyond IMT-2000 should be agreed as a first priority.*

This Recommendation provides the vision and objectives for the further development of IMT-2000 and the development of future systems with capabilities beyond those of IMT-2000. It is the first document in a series of Recommendations that will define such systems. Detailed considerations of the aspects leading towards this Recommendation are outlined in the Annexes to the Recommendation.

The Recommendation gives broad definition of the features of the future IMT-2000 systems under a number of headings in the following two phases: 1) an evolutionary phase (entitled in this Recommendation as ongoing enhancement of IMT-2000) and 2) a subsequent phase (entitled in this Recommendation as systems beyond IMT-2000). The current standardisation of the first releases of IMT-2000 already defined is considered to be a near-term activity and is not considered in this document. The ongoing enhancement of IMT-2000 may be considered as a mid term phase. The definition of systems having capabilities beyond those of IMT-2000 is a longer term goal. Given fast moving technology development, uncertainty in customer base and the desire for long term return of investments in IMT-2000 systems, these time frames cannot yet be quantified with any precision. However, most IMT-2000 licenses currently being awarded will have a lifetime of 15-20 years. The development of systems beyond may overlap the latter part of this period to some extent.

As per Resolutions ITU-R 9, "Liaison and Collaboration with Other Organizations," and ITU-R 50, "Role of the Radiocommunication Sector in the Ongoing Development of IMT-2000," WP 8F will address methods of cooperation and interactions with the ITU-T and external organizations in the appropriate areas within a separate document.

## 3 Related Recommendations

### 3.1 ITU-R

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

ITU-R M.816-1 – Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)

ITU-R M.1390 – Methodology for the calculation of IMT-2000 terrestrial spectrum requirements

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

ITU-R M.1455 – Key Characteristics for the International Mobile Telecommunications (IMT-2000) radio interfaces

ITU-R M.1457 – Detailed radio interfaces for IMT-2000

ITU-R M.1079 – Quality of service aspects for IMT-2000

## 3.2 ITU-T

A Special Study Group on "IMT-2000 and beyond" was created during the World Telecommunication Standardization Assembly (WTSA-2000), Montreal, 2000. This group has the primary responsibility within ITU-T for overall network aspects of IMT-2000 and beyond.

The existing IMT-2000 Recommendations are as shown below:

ITU-T Q.1701 Framework of IMT-2000 networks
ITU-T Q.1711 Network functional model for IMT-2000
ITU-T Q.1721 Information flows for IMT-2000
ITU-T Q.1731 Functional specifications and requirements for IMT-2000 radio interface

# 4 Vision

*Editor's note: the vision details are in Annex 1. Material in Annex 1 that is considered to be essential should be moved forward into this section of the body of the recommendation.*

The high level vision for the ongoing development of IMT-2000 is that there will be a steady and continuous evolution over the next 10 years. Beyond this timeframe, for systems beyond IMT-2000, there may be a requirement for a new radio access technology for the cellular component, sometime after 2010.

Important aspects to be considered are the services context, and the timeframes and phases

## 4.1 Services Context

The trends from a service perspective include integration of services and convergence of service delivery mechanisms. In particular, there are three pillars for future service integration (CCC):

1. Connectivity (provision of a pipe, including intelligence in the network and the terminal)
2. Content (information, including push-pull)
3. Commerce (transactions)

These market trend swill result in new service delivery dunamics and a new paradigm in telecommunications where value added services such as those whichare location dependent will provide enormous benefits to both the end users and the service providers. The convergence will lead to more intelligent use of the communications media, where IMT-2000 will be able to offer the users what they need in any specific mobile environment. The range of applicability of IMT-2000 is very much wider than earlier mobile systems and is expected to include future enhancements which will offer increasingly superior capabilities and performance in low mobility environments.

Hence, IMT-2000 systems will need to support these service trends in an integrated manner (e.g., suitable QoSs for a service mix, content-dependent characteristics, and secure transaction capabilities). Furthermore, IMT-2000 will complement other means of service delivery, including other mobile and fixed wireless access, wireline, broadcasting, etc., hence Convergence of all these systems will need to be considered. There are also many emerging embedded applications and machine-to-machine communications, which will increase the demand for IMT-2000 systems.

In the original version of Recommendation ITU-R M.816 (prior to revision 1) service bit rates of up to 20 Mbit/s were originally envisaged to be supported under favourable circumstances. It is expected that systems beyond IMT should also be able to support spot coverage and 100 Mbit/s+. In the meantime there will be a choice of WLAN chips, based on IEEE 802.11 and HIPERLAN 2 standards, which could be included in mobile terminals to extend their capabilities in certain areas.

## 4.2 Timelines/Phases

A very important aspect for the work of WP 8F is the development of timelines and associated phases. Timelines may be considered from various perspectives:

1. Market requirements and demand (e.g., as per vision decument, market research reports).
2. Planned enhancements of the radio transmission technology for IMT-2000 (e.g., as per Annex to Circular letter 8/LCCE/85).
3. Spectrum availability, including allowing sufficient time to re-locate systems that may be using the band (e.g., as per WRC-2000 agreements).
4. Infrastructure deployment

All four aspects are interrelated. The first three have been addressed within in WP 8F. The latter, infrastructure deployment, relates to the practical aspects of deploying new networks, which include the need to recover previous investments and allowing sufficient time for ironing out the initial difficulties that the deployment of any new major system, such as IMT-2000, may entail.

Two clear phases of IMT-2000 enhancement and development may be envisioned at a global level (although within individual countries or regions the phases may differ markedly): 2000-2005 and 2005-2010. The first phase (up to 2005) is dominated by growth of traffic within existing cellular spectrum. The second phase (2005-2010) dominated by growth within new "IMT-2000" spectrum.

Systems beyond IMT-2000 will primary have market impact in 2015+, but we would need to study them much earlier than that and get a clear idea of suitable spectrum and then develop standards by say 2010 to allow for a major market impact beyond 2015.

## 5 Objectives

*Editor's ~~note~~Note: ~~the~~ The objectives details are in Annex 2. Material in Annex 2 that is considered to be essential should be moved forward into this section of the body of the recommendation.*

The objectives for systems beyond IMT-2000 include the support of global mobility, and therefore, there is a need for the standardisation of the terrestrial air interface specifications and the satellite air interface. The specifications should be finalised in a timely manner prior to system development. In addition, interoperability between different systems is also required to ensure true global mobility.

Ongoing enhancements will increase the information bit rates beyond that currently envisioned for IMT-2000 for all classes of mobility. In the case of T-IMT2000, it is envisioned that peak AMBR[2]

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[2] Recent systems under development are supposed to apply adaptive modulation/coding techniques. These systems change information bit rates according to the propagation conditions, interference, and congestion. Because of this, there may be areas where the maximum possible bit rate cannot be achieved. Therefore, a new definition of throughput will be necessary to evaluate the systems. For example, the area averaged maximum possible bit rate (AMBR) as shown in Equation (1) is a candidate for such a definition.

$$AMBR = \frac{1}{S}\int MBR(s)ds \qquad (1)$$

MBR(s) represents the maximum possible bit rate at a particular geographic point, s is the cell area surrounding that particular point, and S is the total service area under consideration.

will be less than [20 Mb/s] in multi-user and multi-cell environments. Evolution of the S-IMT-2000 systems may result in capabilities exceeding the initial S-IMT2000 offerings of up to 432 kbps.

The satellite and terrestrial components may operate in conjunction with one another to facilitate global coverage.

## 6 Market Trends

Editor's note: the market trend details are in Annex 3. Material in Annex 3 that is considered to be essential should be moved forward into this section of the body of the recommendation.

### 6.1 Delivery Mechanisms

*Editor's Note: The following recommendations should be utilized in the development on the subject areas of Satellite Operation (M.818-1), Requirement for the Radio Interface (M.1034-1) and Framework for the Radio Interface(s) and Radio Sub-System Functionality (M.1035).*

*Editor's Note: Consider the implications of other market developments, e.g. "broadband revolution"; e.g. wired, unwired; radio, optical, infrared.*

#### 6.1.1 HAPS

An IMT-2000 terrestrial system utilizing HAPS consists of communication equipment on one or more HAPSs located by means of station-keeping technology at nominally fixed points in the stratosphere (at about 20 km altitude), one or more ground switching/control stations, and a large number of fixed and mobile subscriber access terminals. The system uses radio transmission technologies (RTTs) that satisfy IMT-2000 requirements to offer high density and high-speed communications capacity to fixed and mobile stations. The HAPS architecture is in concept much like a very tall terrestrial tower that is sectorized into hundreds of cells.

The HAPS telecommunications payload consists of multibeam light-weight reflector or phased-array antennas, transmit/receive antennas for gateway links with ground switching stations, and a very large bank of processors that handle receiving, multiplexing, switching and transmitting functions. The payload can utilize various multiple-access techniques and standards (e.g., TDMA, CDMA) that meet IMT-2000 requirements. The HAPS telecommunications payload can be designed to serve as the sole station in a stand-alone infrastructure (essentially, replacing the tower base station network with a “base station network in the sky”) or can be integrated into a system that employs traditional terrestrial base station towers, satellites, and HAPSs.

A HAPS system will provide mobile cellular coverage and fixed wireless services to several regions ranging from a high-density (urban) area to low-density (rural) areas. The high gain transmit/receive antennas used on the HAPS project a large number of cells onto the ground in a pattern similar to that created by a traditional cellular system. The HAPS cellular coverage will likely include three regions: (i) high-density (urban); (ii) moderate density (suburban); and (iii) low-density.

The system dynamically reassigns capacity among the cells on a minute by minute basis in order to focus the capacity where it is most needed at any given time. For instance, the HAPS can direct additional capacity toward automobile traffic during rush hour and then shift it to a stadium during an evening sports event or performance. This gives the HAPS greater flexibility than traditional systems and can be used along or in concert with traditional terrestrial systems to prevent system overload in hot spots.

## 7 Systems Beyond IMT-2000

Editor's note: the details are in Annex 5. Material in Annex 5 that is considered to be essential should be moved forward into this section of the body of the recommendation.

The General Requirements for systems beyond IMT-2000 include:

– Support terminal and personal mobility
– Usability on variable environments (high/low tier movement, indoor, etc.)
– Roaming and hand-over support to other different systems [and networks]
– Guarantee comparable quality with wire-line network
– Global seamless support
– Global Seamless Service provision
– Support of data rate from [2 Mbps] (full movement) to [20 Mbps] (Still) in new mobile systems

## 8 Spectrum Implications

Editor's note: the spectrum details are in Annex 4. Material in Annex 4 that is considered to be essential should be moved forward into this section of the body of the recommendation.

In the light of the above, there may be a requirement for additional spectrum (globally harmonised) sometime after 2010. This issue may therefore be included on the WRC06 agenda. ITU-R WP8F will undertake studies in this area and will make appropriate proposals to WRC06.

## 9 Enabling Technologies

*Editor's note: the enabling technology details are in Annex 6.*

## 10 System Management and Security

*Editor's note: the system management and security details are in Annex 7.*

## 11 Developing Country Requirements

*Editor's note: the developing country requirement details are in Annex 8.*

## 10 Recommendations

The ITU Radiocommunication Assembly,

*considering*

a) Resolution 737 (GT PLEN-2/2) (WRC-2000);

b) Resolution 228 (GT PLEN-2/3) (WRC-2000);

c) Question ITU-R 229/8 on Future development of IMT-2000 and systems beyond IMT-2000;

{Note: considering d) has been deleted since it is not a meaningful statement}

e) that the use of internationally agreed frequency bands facilitates the planning of national networks that can support worldwide roaming, and avoids the risk of harmful interference with other radio services;

f) the increasing importance of various types of non-voice telecommunication services;

g) that a phased approach was adopted in Recommendation ITU-R M.687 for IMT-2000 in which Phase 1, the initial phase of IMT-2000 operation, includes terrestrial services supported by data rates up to approximately 2 Mbit/s, and satellite services up to approximately 144 kbit/s, and Phase 2 is envisaged as augmenting Phase 1 with new services, some of which may require higher bit rates;

h) that standardized radio interfaces facilitate the roaming of mobile units between networks;

j) that the satellite component, as an integral part of IMT-2000, can facilitate in providing global coverage for IMT-2000;

k) that the distinction between fixed, mobile and broadcasting services is becoming increasingly blurred as services become increasingly integrated;

{Note: there seemed to be duplication in (k) and (l) and hence considering l has been deleted}

m) that new applications such as mobile multimedia services and mobile commerce are likely to drive the demand for mobile systems including IMT-2000 and beyond;

n) that spectrum for IMT-2000 is identified in S5.388 (WARC-92) and [S5.384A, S5.317A, S5.351A and S5.388A] (WRC-2000) of the Radio Regulations;

o) that WRC-03 will consider progress on studies on the ongoing enhancement of IMT-2000 and systems beyond, in line with Resolution 228 (WRC-2000), with a view to WRC-05/06 considering frequency allocations,

*noting*

a) that advances in technology will allow the capabilities of IMT-2000 to be extended and new systems beyond IMT-2000 to support new applications for new market sectors,

*recommends*

*Editor's Note: Consideration should be given to categorize the recommends into areas related to vision and areas related to objectives. Vision and objectives are discussed in further detail in Annex 1.*

**1** that, based on the considerations above and the more detailed considerations in Annexes [1,2,3 etc] of this Recommendation, the objectives for the ongoing enhancement of IMT-2000 and of systems beyond IMT-2000 should be as follows:

**1.1** that the capabilities of IMT-2000 should continue to be extended throughout its lifetime to the extent demanded by the market and allowed for by technical advances, in the context of providing advanced multimedia services on a global basis;

**1.2** [that, alongside the ongoing development of IMT-2000, applications beyond IMT-2000 should be considered to support new applications and market opportunities not likely to be supportable on IMT-2000, as identified in
Annexes [1, 2, 3 etc.] of this Recommendation];

**1.3** Ongoing enhancements of IMT-2000 Systems are as follows:

**1.3.1** [Radio Transmission Technologies (RTTs) for the terrestrial component should not be more diverse than the five (5) existing radio interfaces found in ITU-R Recommendation M.1457 in order to avoid divergent technologies];

**1.3.2** [Enhancements to IMT-2000 radio access methods should focus on enhancement of the existing radio interfaces rather than on the development of new radio interfaces;]

**1.3.3** [Enhancements to IMT-2000 RTTs should be compatible with frequency identifications and usage for IMT-2000 (WRC-92, WRC-00)];

**1.4** Future systems beyond IMT-2000 are as follows:

{Note: this statement is premature. Whilst the suggestion is certainly an option, the technical requirements and practical possibilities for "systems beyond" are not yet established.}

Annexes: **8**

ANNEX 1

**Detailed Considerations in the development of the vision of ongoing development of IMT-2000 and systems beyond**

*(Editor's Note: These may be better in main body of the Recommendation to avoid repetition.)*

*Editor's Note: Consideration should be given to a separate annex on the vision aspects and on the objective aspects of IMT-2000 and systems beyond.*

## 1 Vision and Timeframes

*Editor's Note: In this sub-section, the differences between ongoing enhancement of IMT-2000 and systems beyond IMT-2000 should be described.*

It is expected that the further development of IMT-2000 will increase its capabilities for a considerable period; in the longer term, these capabilities will be complemented by the introduction of systems beyond IMT-2000. The capability of a mobile system include the following elements:

– Range of bit rates supported
– Increased support for IP (including QoS)
– Number of frequency bands supported
  – Range of operating environments.
  – A range of mobility options
  – A range of multi-mode terminals
– Extent of support for global roaming.

In this Recommendation, the further development of IMT-2000 and the expected development of systems beyond is considered as being separated into two indicative time frames.

IMT-2000 supports frequency division duplex (FDD) and time division duplex (TDD) to enable symmetric and asymmetric data services in a spectrum efficient way. Third generation systems are addressing a mass market for mobile multimedia communications and enhanced multimedia services.

The vision for the further development of mobile communications beyond third generation will mainly be driven from the user perspective, which can be described as a combination of several communication levels. In the first level the user connects all carried devices like a camera, phone, mirror glasses for images, watch etc. in a PAN (Personal Area Network) by short range connectivity systems. The second level links the immediate environment like a TV, a PC, a refrigerator etc. to the user. Level three ensures the direct communication to instant partners as other users and vehicles. Different radio access systems like terrestrial systems, satellite systems and HAPS (High Altitude Platform Stations) are provided in level four for full area coverage. These levels are surrounded by the Cyber World (services and applications domain) in level five, where games, access to databases and the Internet, communication etc. are provided. Therefore, the different communication relations person to person and mainly machine to person and vice versa and machine to machine will determine mobile and wireless communications in future.

Several access technologies are evolving and emerging. In addition to second and third generation mobile communication systems, broadband WLAN type systems as HIPERLAN 2, IEEE 802.11 and broadcast systems as DAB and DVB-T are becoming available. For short range connectivity systems like Bluetooth are being developed. In the fixed access, systems as xDSL and in particular

ADSL are increasing the user data rate significantly on the last mile. Fixed wireless access or wireless local loop systems are developed to replace or complement wired access systems. All these technologies will be part of systems beyond third generation, which are applicable to data communications. The combination of these technologies represents a very flexible and powerful platform to support future requirements on services and applications, which will be part of mobile communications beyond third generation. In addition, research activities are starting to develop new radio interface concepts, which may support higher data rates with higher mobility than current third generation systems.

The vision from the user perspective can be implemented by integration of these different evolving and emerging access technologies in a common flexible and expandable platform to provide a multiplicity of possibilities for current and future services and applications to users in a single terminal. Systems beyond third generation will mainly be characterized by a horizontal communication model, where different access technologies as cellular, cordless, WLAN type systems, short range connectivity and wired systems will be combined on a common platform to complement each other in an optimum way for different service requirements and radio environments. These access systems will be connected to a common, flexible and seamless core network. The mobility management will be part of a new Media Access System as interface between the core network and the particular access technology to connect a user via a single number for different access systems to the network. This will correspond to a generalized access network. Global roaming for all access technologies is required. The interworking between these different access systems in terms of horizontal and vertical handover and seamless services with service negotiation including mobility, security and QoS will be a key requirement, which will be handled in the newly developed Media Access System and the core network.

This vision ***"Optimally Connected Anywhere, Anytime"*** results in a seamless network including a variety of interworking access systems (Figure 2), which are connected to a common IP based core network. The Media Access System connects each access system to a common core network. Due to the different application areas, cell ranges and radio environments the different access systems are organized in a layered structure (according to Figure 3) similar to hierarchical cell structures in cellular mobile radio systems. However, in addition to different cell layers also different access technologies are complementing each other on a common platform. Multi mode terminals and new appliances are key components, which will be adaptive based on software defined radio technology using high signal processing power.

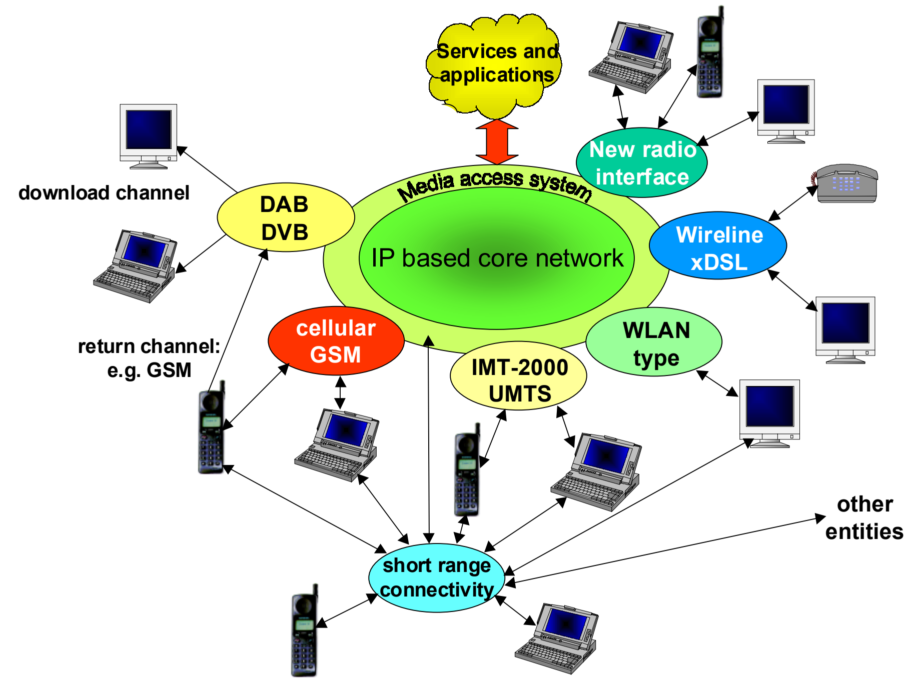


FIGURE 1

**Seamless future network including a variety of interworking access systems**

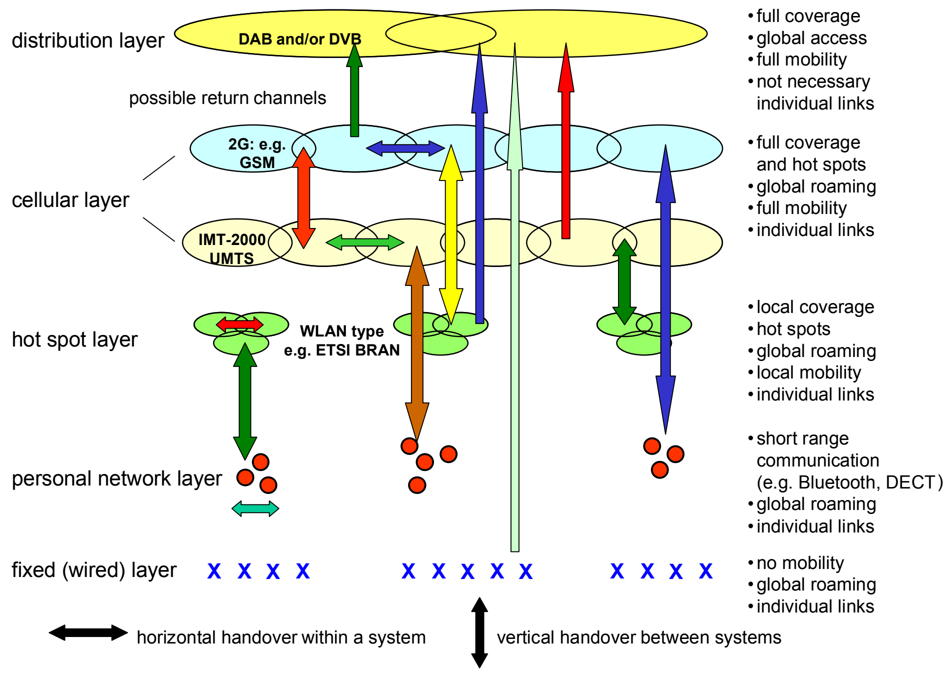


FIGURE 2

**Medium Term**

In the medium term (up to 10-15 years), it is envisaged that the further development of IMT-2000 will progress well beyond the capabilities of the initial deployments, as demanded by the market and allowed by the status of technical developments. There could be significant progress towards harmonization of the radio interfaces It is envisaged that the bands identified by the WRC-2000 will be made available for IMT-2000 within this time-frame, subject to market demand and other considerations.

**Longer Term**

The longer term is associated with the introduction of systems with capabilities beyond those envisaged as being appropriate to an "evolved" IMT-2000. It is envisaged that these systems will add significant new capabilities (possibly much higher user data rates)and they will probably be supported by additional frequency bands above 3GHz. It may be possible that some of the more basic capabilities of IMT-2000 will not be offered by the systems beyond IMT-2000. However, it is envisaged that certain core capabilities will be common to both evolved IMT-2000 and the systems beyond IMT-2000 (see figure 1).

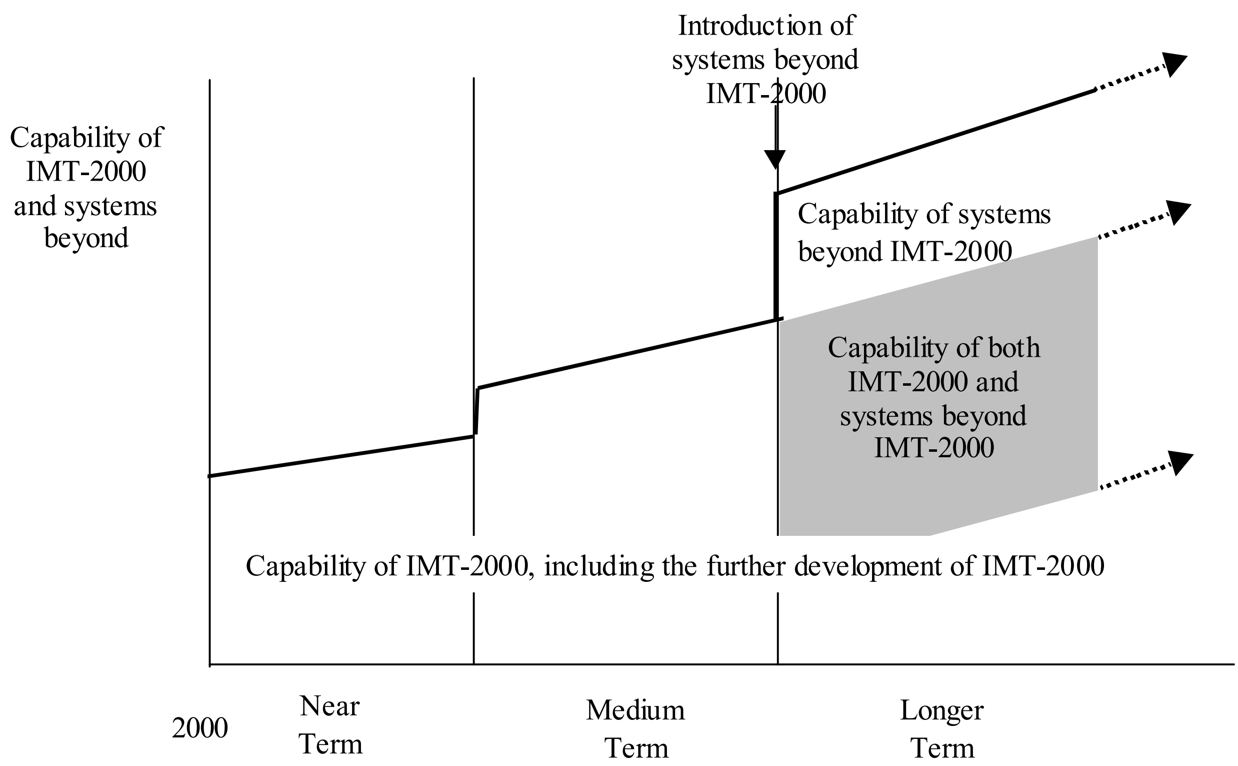


FIGURE 1

**Capability of IMT-2000 and systems beyond**

## 2. Services and Applications

Multimedia services and applications with various information speeds will be widely used in the future. Considering the accessibility to services on the Internet in the future, support of IPv6, Voice over IP (VOIP), Quality of Service (QoS), multicast, and real time applications end to end will be required. This should take into account the Quality of Service (QoS) requirements of both real time and non-real time applications. A system capability that enables users to access either the 3G, systems beyond IMT-2000 and wireless private networks such as wireless LANs and also enable seamless roaming between heterogeneous networks without interruption will be requested as well. In addition, geo-location services using air-interface signals and its applications will play an important role in future mobile services. This specification must clearly define which of these services the IMT-2000 network will provide and which will simply be transported by it.

## 3. System capabilities

Initially IMT-2000 achieves transmission bit rates of up to 2Mbit/s. Ongoing enhancement will incrementally increase these transmission bit rates.

A peak data rate of 100 Mbit/s by wired LAN is now common in offices, and wireless LANs achieve information bit rates of several tens Mbit/s. Data rates significantly greater than 2Mbit/s seems an appropriate medium-term target for IMT-2000 systems working co-operatively with these and other delivery platforms as the mobile element of a convergence scenario.

The evolution of mobile communication systems beyond 3G will include continuous improvements of the systems and their integration into a “network of networks“, including systems for short range connectivity as well as broadcast systems.

The mobile elements of systems beyond IMT-2000 might need to offer data rates significantly greater than 20Mbit/s, otherwise they will not really fulfil the definition of "systems beyond".

## 4. Deployment Scenarios

The target capabilities of service beyond IMT-2000 can be covered by a unified system (which may encompass multiple modules) to be developed in the future, or by multiple platforms including the mobile (terrestrial/satellite) systems that already exist today or are being developed.

{Note: The appropriate deployment options for "stand-alone" or "multi-platform" scenarios need to be addressed in this section}.

## 5. Roadmap to the future development of IMT-2000 and Systems beyond IMT-2000

*Editor's Note: This sub-section describes the targets of the ongoing enhancement of IMT-2000 and Systems beyond IMT-2000 with time scales. The ongoing enhancement of IMT-2000 would be described as a milestone to the future systems beyond IMT-2000. The systems beyond IMT-2000 would also be described as a mile stone to the convergence world or a part of the convergence world.*

ANNEX 2

**Detailed Considerations in the development of the objectives of ongoing development of IMT-2000 and systems beyond**

# 1 Objectives

## 1.1 General objectives

### 1.1.1 Degree of Standardization and Timing

To support global mobility, the air interface specifications should be standardised. It should be noted that as the satellite operating environment is different to that of terrestrial cellular systems the two air interfaces may need to be different. However, multi-mode terminals can enable access to both types of networks and therefore fulfil the vision of global access.

The air interface specifications, in each case, should be finalised in a timely manner prior to system development.

### 1.1.2 Time scale to the future development of IMT-2000 and Systems beyond IMT-2000

Future development of IMT-2000 should be considered as mid term range [up to 10 or 15 years from now].

Systems beyond IMT-2000 should be considered as longer term range [10 years onwards].

## 1.2 Technical Objectives

It is highly expected that the enhanced systems of IMT-2000 and systems beyond may offer the integrated services of broadcasting and wireless communication. Since many advanced wireless communication technologies have been being developed, the implementation issues of system to launch the new services might be easier. Thus, prior to determination of the future system features, it is valuable to consider what kind of services are going to be provided in the future.

According to the trend of services, the future systems such as terrestrial wireless interactive multimedia systems, which comes from the terrestrial components of enhanced systems of IMT-2000 and systems beyond, is expected have to consider the following items:

– seamless services across various wireless systems and networks;

– global roaming service between existing systems and the future systems;

– appropriate technologies to employ the future services.

When the future system is developed, items mentioned above have to be considered. In current Vision PDNR, there are many requirements and considerations of system features. On the other hand, the contents of future services are insufficient in the current PDNR. Thus, it is required to discuss the future services in Vision Working Group.

When launching the services using the future systems, it will be appeared the enhanced services and new services. After several years from now, it is expected that there are many enhanced services using the future systems in the world. For example:

1) The enhanced services

- Location information service offering multimedia geographical information in detail

- Wireless internet education service
- Mobile computing service dealing with the multimedia data processing
- Emergency service : vehicles repair and life rescue
- Remote health care service
- Internet videophone service
- Wireless internet home shopping and banking service
- Wireless internet broadcasting and news service
- VOD service.

2) The new services

- High quality image service : HDTV broadcasting service
- Wireless services according to various QoS
- Multimedia service connected to satellite communication service
- Wireless interface selection service according to the user terminal capability.

To consider the trend of future services, it is proposed that WP 8F need to discuss the system features as well as the future services.

## 2.1 The Ongoing Enhancement of IMT-2000

### 2.1.1 Target of Mobility and Information Bit Rate

Ongoing enhancements will increase the information bit rates beyond that currently envisioned for IMT-2000 for all classes of mobility. It is envisioned that peak AMBR[3] may be less than [20 Mb/s] in multi-user and multi-cell environments.

### 2.1.2 Coverage

The satellite and terrestrial components may operate in conjunction with one another to facilitate global coverage.

### 2.1.3 Security

Authentication protocols are required between public and private networks to support a seamless service. These authentication and security services will address both the needs of the user and the network itself. The protocols must also support a single user having multiple IMT-2000 devices that are in use simultaneously.

[3] Recent systems under development are supposed to apply adaptive modulation/coding techniques. These systems change information bit rates according to the propagation conditions, interference, and congestion. Because of this, there may be areas where the maximum possible bit rate cannot be achieved. Therefore, a new definition of throughput will be necessary to evaluate the systems. For example, the area averaged maximum possible bit rate (AMBR) as shown in Equation (1) is a candidate for such a definition.

$$AMBR = \frac{1}{S}\int MBR(s)ds \qquad (1)$$

MBR(s) represents the maximum possible bit rate at a particular geographic point, s is the cell area surrounding that particular point, and S is the total service area under consideration.

### 2.1.4 Implementation

e.g. hardware/software, radio issues (including smart antennas), network issues (transmission quality target defined in terms of BER and delay for multiple service classes), Congestion control for wireless QoS.

#### 2.1.4.1 Radio Issues

#### 2.1.4.2 Network Issues

*Editor's Note: The following recommendations should be utilized in the development on the subject areas of Network Architecture (M.817) and Performance Requirement/QoS (M.1079).*

## 2.2 Systems Beyond IMT-2000

From the user perspective the vision for mobile communications can be described as a multi sphere level concept. In the first level the user connects all carried devices like a camera, phone, mirror glasses for images, watch etc. in a PAN (Personal Area Network) by short range connectivity systems. The second level links the immediate environment like a TV, a PC, a refrigerator etc. to the user. Level three ensures the direct communication to instant partners as other users and vehicles. Different radio access systems like terrestrial systems, satellite systems and HAPS (High Altitude Platform Stations) are provided in level four for full area coverage. These levels are surrounded by the Cyber World (services and applications domain) in level five, where games, access to databases and the Internet, communication etc. are provided. Therefore, the different communication relations person to person and mainly machine to person and vice versa and machine to machine will determine mobile and wireless communications in future.

This vision from the user perspective is the driving force for seamless services and applications via different access systems for future developments. Due to the future dominating role of IP based data traffic and applications, networks and systems have to be designed for economic packet data transfer. The fixed Internet penetration is growing in parallel to the mobile radio access penetration. About 80 % of fixed Internet users are also using mobile communications. Therefore, these users want to get the same services also on mobile terminals. These services require a high degree of asymmetry between uplink and downlink especially for Internet type services with much higher expected capacity on the downlink.

Several access technologies are evolving and emerging. In addition to second and third generation mobile communication systems, broadband WLAN type systems as HIPERLAN 2, IEEE 802.11 and broadcast systems as DAB and DVB-T are becoming available. For short range connectivity systems like Bluetooth are being developed. In the fixed access, systems as xDSL and in particular ADSL are increasing the user data rate significantly on the last mile. All these technologies will be part of systems beyond third generation, which are applicable to data communications. The WLAN type systems are designed in particular for high data rate access, low range and in general for low mobility. They are applicable for corporate networks and public access for hot spot applications as complement to cellular mobile radio systems (e.g. GSM and IMT-2000 / UMTS). Fixed wireless access or wireless local loop systems are developed to replace or complement wired access systems. DAB and DVB-T can be applied to wideband broadcasting data services in the downlink. These systems can be combined with cellular mobile radio systems as GSM and UMTS and the PSTN and ISDN for the uplink as return channel for user requests and highly asymmetrical services. The combination of these technologies represents a very flexible and powerful platform to support future requirements on services and applications, which will be part of mobile communications beyond third generation. In addition, research activities are starting to develop new radio interface concepts, which may support higher data rates with higher mobility than current third generation systems.

This vision from the user perspective can be implemented by integration of these different evolving and emerging access technologies in a common flexible and expandable platform to provide a multiplicity of possibilities for current and future services and applications to users in a single terminal. The available, emerging and evolving access technologies have basically been designed in the classical vertical communication model that a system has to provide a limited set of services to users in an optimized manner. Systems beyond third generation will mainly be characterized by a horizontal communication model, where different access technologies as cellular, cordless, WLAN type systems, short range connectivity and wired systems will be combined on a common platform to complement each other in an optimum way for different service requirements and radio environments. These access systems will be connected to a common, flexible and seamless core network. The mobility management will be part of a new Media Access System as interface between the core network and the particular access technology to connect a user via a single number for different access systems to the network. This will correspond to a generalized access network. Global roaming for all access technologies is required. The interworking between these different access systems in terms of horizontal and vertical handover and seamless services with service negotiation including mobility, security and QoS will be a key requirement, which will be handled in the newly developed Media Access System and the core network.

### 2.2.1 Target of mobility and information bit rate

Systems beyond IMT-2000 may handle a wide range of supported data rates according to economic and service demands with ~~achieve~~ an AMBR of greater than 20 Mb/s for systems in multi-user and multi-cell environments and with terminals moving at vehicular speeds. Flexible allocation of the required system capacity will be provided.

### 2.2.2 Coverage

From the user's viewpoint, it is important to cover a wide service area equivalent to the present IMT-2000 systems. It is necessary to cover vehicular environments as well as local area (indoor offices, homes and business premises). There are several radio operating environments, and radio systems are designed taking into account of the assumed operating environments. By taking advantage of seamless service, the service area in different environments can be covered in a complementary manner by several systems. The satellite and terrestrial components may operate in conjunction with one another to facilitate global coverage. The possibility to use of a common frequency band world-wide is a desirable goal. Economic deployment of systems in the entire coverage area with optimized radio interfaces for

- macro cells
- micro cells
- indoor, hot spots and
- broadcast

will be required.

### 2.2.3 Security

Authentication protocols are required between public and private networks to support a seamless service. These authentication and security services will address both the needs of the user and the network itself. The protocols must also support a single user having multiple IMT-2000 devices that are in use simultaneously.

### 2.2.4 Implementation

#### 2.2.4.1 Radio issues

*Editor's note: The following point is raised to stimulate discussion and contribution: should the radio interface be an extension of the network technology that it is bearing?*

- **Air Interface Specification**

  A new air interface specification may be required for systems beyond IMT-2000 in order to achieve higher bit rate data services and enhance the efficiency of spectrum utilisation. The Air interfaces should be capable of supporting multi-mode terminals providing multi-services in a multitude of environments.

- **Capacity/Throughput/Spectrum efficiency**

  The amount of traffic is likely to continuously increase. The capacity of the system could be enhanced significantly by adopting evolving technologies, for instance using "smart" antennas.

- **Multi-mode terminal**

  In order to support seamless access to applications and services in a multi-platform scenario, a compact multi-mode terminal with sufficient battery power is desirable.

#### 2.2.4.2 Network issues

*Editor's Note: The following recommendations should be utilized in the development on the subject areas of Network Architecture (M.817) and Performance Requirements/QoS (M.1079). Congestion control for wireless QoS should also be addressed.*

Considering connectivity with the Internet and studies on an IP-based network architecture by 3GPP and 3GPP2, the systems beyond the IMT-2000 should be based on IP technologies or more advanced technologies. In addition to studies on network aspects by the ITU-T and other standardization bodies, the ITU-R may wish to study advanced network control in radio access networks (RANs) including mobile terminals.

It is to be expected that the future Internet will provide extensive support of mobility as well as enhanced security mechanisms, QoS also for real-time services and a greatly enlarged address room (IPv6). Interoperation, e.g. marriage of new IP based networks with established carriers, will be a necessity. While at current the quality of video streaming over the Internet is barely acceptable, multimedia transmission including reasonable video transmission quality and real-time services including interactivity over the web will soon become a reality and may change broadcasting for ever. Life feeds from around the world or content on demand, as and when a user requests it, will be delivered over the Internet. This will also greatly influence the requirements for mobile networks.

## 3 Operational Objectives

### 3.1 Operational Consideration Towards The Convergence World

*Editor's Note: Consideration of aspects with respect to the work of JTG 1-6-8-9 on convergence and new terrestrial wireless interactive multimedia technologies and applications.*

#### 3.1.1 Regulatory and Standardization

*Editor's Note: This may contain information of concern to JTG 1-6-8-9.*

Reconfigurable radio technology is acknowledged by FCC, the US regulatory authority, as an important mechanism to allow the modernization of spectrum engineering practices to improve spectrum efficiency.

For the longer-term vision of reconfigurable air interfaces, deregulation of spectrum and minimal standardization are key to breaking down the 'Generation' cycle in mobile communications, where years of standardization work, resulting in the release of the 'next' generation system, may well be already outdated by technology advances. The vision of a flexible, scalable system into which new technology developments may be easily integrated, could potentially minimize standardization requirements, specifying only fundamental communication mechanisms such as:

- An interface for connecting new radio access points to the converged backbone network;
- A communications channel to the terminal over which spectrum access is negotiated, or evolution of an adequate spectrum-access etiquette;
- A mechanism by which spectrum access may be policed (for example, consideration of the case where a software radio pollutes local spectrum, having downloaded and installed software which causes rogue emission).

Furthermore, the role of regulators will require evolution, possibly focussing on :

- Policing user privacy and security in a scheme where user profiles, configuration information, and a significant quantity of personal data is stored and widely distributed. Security and privacy measures must be jointly agreed by industry and regulations to resolve potential conflicts, for example between users and the advertisement industry
- Ensuring fair access to spectrum through real-time policing and prevention of service monopolies

However, the huge investment in legacy systems will ensure that 2G and 3G cellular schemes will be retained for many years. The key is to establish the business model and technologies through which an evolved uniform, scalable system may be adopted as and when segments of spectrum are released.

## 3.2 The Ongoing Enhancement of IMT-2000

### 3.2.1 System Management

*Editor's Note: The following recommendation should be utilized in the development on the subject area of System Management (M.1168).*

# 4 Service Objectives

One key aspect of IMT-2000 systems is that they will be based on defined "service capabilities", rather than on defined services. These standardised capabilities will provide a defined platform enabling the support of speech, video, multi-media, messaging, data, user applications and supplementary services, while enabling the market for services to be driven by users . This approach will ensure that operators will be capable of rapid development and deployment of competitive service offerings

Support IP-packet data for both real time and non-real time applications for "mid-term" developments.

ANNEX 3

**Detailed Considerations on market requirements for ongoing development of IMT-2000 and systems beyond**

~~**Market Requirements**~~

## 1 Market Trends

The number of subscribers for mobile communications has increased much faster than expected. Annual growth rates in important markets increased from 1998 with about 60 % to expected 100 % per year in 2002. In 2000 the number of mobile subscribers is higher than 400 million worldwide and for 2010 more than 1700 million mobile subscribers are expected worldwide. With third generation systems the combination and convergence of the different worlds IT industry, media industry and telecommunications will integrate communication with information technology. It is expected by the UMTS Forum that in Europe in 2010 more than 90 million mobile subscribers will use mobile multimedia services and will generate about 60 % of the traffic in terms of transmitted bits. These different types of services can be subdivided into individual services like multimedia, e-mail, file transfer etc., symmetrical and asymmetrical services, real-time and non real-time services and distribution services like radio, TV and software provision. The major step from the second to the third generation was the ability to support advanced and wideband multimedia services. The user expectations are increasing with regard to a large variety of services and applications with different degree of quality of service (QoS), which is related to delay, data rate and bit error requirements. Therefore, seamless services and applications via different access systems will be the driving forces for future developments. It is expected that due to the dominating role of mobile radio access the number of portable handsets will exceed the number of PCs connected to the Internet around 2004. Therefore, mobile terminals will be the major man machine interface in the future instead of the PC. Due to the dominating role of IP based data traffic in the future the networks and systems have to be designed for economic packet data transfer. The expected new data services are highly bandwidth consuming. This results in high data rate requirements for future systems.

## ~~4.1.1~~2 Delivery Mechanisms

*Editor's Note: The following recommendations should be utilized in the development on the subject areas of Satellite Operation (M.818-1), Requirement for the Radio Interface (M.1034-1) and Framework for the Radio Interface(s) and Radio Sub-System Functionality (M.1035).*

Consider the implications of other market developments, e.g. "broadband revolution"; e.g. wired, unwired; radio, optical, infrared.

## ~~6.2~~3 Traffic Consideration

Include updated traffic predictions

ANNEX 4

**Detailed Considerations on spectrum implications of ongoing development of IMT-2000 and systems beyond**

# 1 Spectrum

## 1.1 General Considerations

### 1.1.1 Mid-Term

In "mid-term" time frame development will utilise frequency bands identified/intended for use by IMT-2000 at WARC-92 and WRC-2000.

In evaluation of these new frequencies as identified by WRC (WRC-92 and WRC-00), factors that relate to the delivery of multimedia applications, such as high downlink data rates, should be taken into account. For this evaluation the traffic asymmetry, uplink and downlink spectrum requirements, regional band plans, global roaming, advances in technology and current or planned future usage of the frequency bands need to be taken into account.

### 1.1.2 Longer Term

To meet longer-term requirements for IMT-2000 enhancement and beyond, consideration of new frequency bands may be required. Factors that relate to the delivery of multimedia applications, such as high downlink rates, should be taken into account since this will have a strong impact on the spectrum requirement. Other factors to consider in the determination of spectrum requirements include market forecasts of requirements for new applications and services, technology trends, transmission distance (wide area coverage or short range links), interactivity, mobility, etc.

Because it is envisaged that wireless telecommunication services in the long-term time frame will offer individual users greater than 20-Mb/s data-rates, a broader frequency bandwidth may be required. Considerations to achieve these channels include higher spectrum efficiency, dynamic, flow of traffic, packet data techniques, advanced antenna systems, use of micro/pico cells and others. Therefore, additional radio frequency spectrum above that currently identified for IMT-2000 may be required and therefore there should be considerations for further studies for the systems beyond IMT-2000. However, this will first require a furtherl understanding of the market developments in terms of services, rates of delivery, quality of service and cost of implementation as well as end user costs before estimates of spectrum requirements can be assessed.

## 1.2 Factors Influencing Spectrum Requirements

*Editor's Note: This section may include the following items:*

- *Necessity of global harmonization*
- *Roaming requirements*
- *Global roaming*
- *Inter-system roaming*
- *Satellite communications*
- *High Altitude Platform (HAP) communications*
- *Duplex techniques*

- *Radio propagation*
- *RF technology and spectrum efficiency*

### 1.2.1 Spectrum for broadband wireless communications

### 1.2.2 Radio propagation

{Note: As per the normal arrangements within ITU-R, WP8F should seek appropriate propagation advice from Study Group 3}

## 1.3 Preliminary Spectrum Estimation

*Editor's Note: The Spectrum working group in WP 8F will study spectrum requirements.*

## 1.4 Sharing possibilities with other services

*Editor's Note: Aspects are also related to work with the 8F Spectrum Working Group.*

### 1.4.1 National Cross Border Spectrum Coordination Aspects

~~Enabling Technologies~~

## ~~4.2 Technology Trends~~

~~*Editor's Note: Aspects for further discussion include Adaptive Antennas and Software Defined Radios (SDR), contributions are expected on additional topics at further meetings.*~~

ANNEX 5

**Detailed Considerations on ~~spectrum implications~~capabilities of ongoing development of IMT-2000 and systems beyond**

## 1 Capabilities for the System Beyond IMT-2000

### 1.1 General Requirements

– Support terminal and personal mobility
- Flexible allocation of required system capacity
– Usability on variable environments (high/low tier movement, indoor, satellite, etc.)
– Seamless service via different technologies. Global ~~Roaming~~ roaming and hand-over support to other different systems
– Provision of QoS for real time services and efficient transport of packet oriented services. Guarantee comparable quality with wire-line network
– Global seamless support of a wide range of services including symmetrical and asymmetrical services
– Support of a wide range of data rates according to economic and service demands from [2 Mbps] (full movement) up to about [20 Mbps] and beyond (~~Still~~stationary or nearly so) in new mobile systems
- Requirements for Future Mobile Communications from the End-User Perspective
- Efficient support of broadcast and distribution services
- Economic deployment of systems in the entire coverage area with optimized radio interfaces for macro cells, micro cells, indoor, hot spots and broadcast
- Allocation of significant parts of the system complexity to the base station to simplify terminal implementation
- Reconfigurability of network entities and terminals

Systems beyond IMT-2000 will have to support a wide range of symmetrical and asymmetrical services. QoS for real time services and efficient transport of packet oriented services is required, as well as the efficient support of broadcast and distribution services. Seamless service will have to be provided via different technologies, supported by global roaming, as well as the efficient support of broadcast and distribution services.

Allocation of significant parts of the system complexity to the base station shall be envisaged in order to simplify terminal implementation. Reconfigurability of network entities and terminals will be necessary.

### 1.2 Requirements for Future Mobile Communications from the User Perspective

Given the increasing demand of flexibility and individuality in the society, the mean for the end-user must be assessed. Potentially, the value would be in the diversity of mobile applications, hidden from the complexity of the underlying communications schemes. This complexity would be abstracted into an intelligent personality management mechanism, learning and understanding the needs of the user, and controlling the behavior of their reconfigurable terminal accordingly in terms of application behavior and access to the supporting services.

Collaborative research work attempts to rationalize this 'seamless wireless utopia' by studying the 'real' requirements for reconfigurable terminals and creating realistic working scenarios. Technology research will identify the system support concepts, enabling technologies and standardization required to realize the scenarios, and through subjective evaluation, system modeling and simulation, will evaluate the feasibility of the proposed solutions.

Table 1 shows the dominant high level requirements for reconfigurable radio from the perspectives of users, application/content providers, service providers, network operators and equipment manufacturers. Based on these requirements, the demands on the end-to-end system concepts and corresponding enabling technologies may be derived.

TABLE 1

**End user high level requirements**

| | |
|---|---|
| **END USER HIGH LEVEL REQUIREMENTS** | |
| Ubiquitous mobile access | Robust connection is essential<br>*Access to mobile-specific web, multimedia, broadband and broadcast content: seamless handoff between radio access modes (user not interested in which ones).*<br>Service discovery and transparent dynamic adaptation of applications to match available services and preference profiles; home country roaming will become an issue for users<br>Global roaming (important for only a small subset of potential users) |
| Quality expectations vary with task | Service degradation and dropped service (e.g. broadcast TV, interactive games, voice telephony) must be managed. Similar levels of service are expected on the train as in the home.<br>User must have high-level control where cost is concerned. |
| Ease of access to applications and services | Current technologies will set benchmarks (e.g. Internet download)<br>Transparent discovery and switching between services and radio access modes, based on an intelligent establishment and interpretation of user preferences and application requirements. However, some users will require more control for private vs. business use. |
| Low cost and relevant services and meaningful billing | Intelligent discovery, presentation and selection of service options and billing schemes; distribution of application processing between network and terminal to reduce terminal resource requirement.<br>Billing should hide some of the inherent system complexity, i.e. only one bill.<br>Set cost constraints for services |
| Technology comfort | User friendly consumer product model versus computer (PC) model: computer-literacy should not be required but may be useful. Intelligent client-server management schemes must offer freedom from complex PC-like application installation and configuration; but users may still want some control;<br>User-friendly handling of delays, disconnections and new connections via meaningful feedback to the user;<br>Transparent handling of version/configuration control for application and system software (including radio access stack software) and accountability of system to user for reconfiguration changes.<br>Support expected from the service provider and operator in finding services and updating software.<br>Intelligent use of battery resource, both locally (local application, display, sound) and in network access<br>Simple UI and appealing aesthetic. |
| Reasonable equipment life | Expectation that terminal equipment will offer support for fast-evolving complexity and diversity of applications and services |
| **APPLICATION DEVELOPER/CONTENT PROVIDER** | |
| Common Execution Environment | Allowing development of applications and associated content independently of underlying network services and terminal capabilities: self-configuration via capability exchange |
| Application Diversity | Terminals capable of supporting fast-evolving complexity and diversity of applications and services;<br>Utilization of increasing terminal resources to enrich application (eg spare DSP processing capacity) |

| | |
|---|---|
| **SERVICE PROVIDER** | |
| Fast, open service creation, validation and provisioning | Allowing development of services independently of underlying network services;<br>Provisioning of validated services configured to underlying network and terminal capabilities |
| Inform user of services available | Requirement for an effective scheme to 'advertise' available services in a service discovery negotiation |
| Maintain connections and adapt to required QoS | *Ability to seamlessly switch connections to alternate radio access schemes or alternate network operators both in call and in standby*<br>*Dynamically modify resource allocation to maintain desired QoS over radio channels* |
| **NETWORK OPERATOR** | |
| Maximize utilization of allocated spectrum | Flexible allocation of spectrum according to differing user demands.<br>Radio resource and network management to support coexistence of access schemes within allocated bands and spectrum sharing between operators. |
| Maintaining QoS | Maintenance of Quality of Service is a fundamental measure of network operator performance |
| Longevity and flexibility of network equipment | Supporting reconfiguration in the radio access equipment and the media access fabric interfacing to the core network |
| Owning customers | Mechanisms to support operator control of terminals, at all levels |
| **TERMINAL AND COMPONENT MANUFACTURER** | |
| Economies of scale | Consolidation of product variants onto reconfigurable product platforms |
| Bug fix and software enhancement provisioning | Ability to download and install software to overcome bugs and enhance functionality/performance reduces recall costs and increases differentiation and revenue stream |
| Fast product creation | Reconfigurable IP authoring fostering maximized reuse, hardware/software codesign and platform-based IP integration methodology |

## 2 Technical characteristics

### 2.1 System architecture

*Editor's Note: ITU-T address these subjects.*

### 2.2 Implications of network performance

*Editor's Note: The following may be considered.*

- *Quality of service*
- *Speech quality*
- *Data Transmission*

Latency

### 2.3 Radio transmission considerations

*Editor's Note: The following may be considered.*

- *Multiple access*
- *Packet access*
- *Modulation techniques and coding*

## 3 Operational characteristics

*Editor's Note: To facilitate the development of PDNRs informative attachments are included as placeholders to maintain continuity of the areas under discussion between meetings. The informative attachments contain many kinds of information related to the PDNRs main body. These are areas under discussion, background information, new technologies for future systems, statistics of telecommunications and so forth.*

### 3.1 Systems Beyond IMT-2000

### 3.2 System Management

*Editor's Note: The following recommendation should be utilized in the development on the subject area of System Management (M.1168).*

ANNEX 6

**Considerations on Enabling Technologies**

~~Enabling Technologies (the technologies which could or will be used)~~

## 1 Technology Trends

### 1.1 Technology perspective

The overwhelming growth of Internet usage is one of the major technical trends for future communications. The growth of subscriber numbers for fixed access will reach saturation around 2004 for voice usage. Mobile radio access is increasing very fast and the number of mobile subscribers is expected to exceed the number of fixed subscribers also around 2004. The penetration of Internet access over fixed networks is growing in parallel to the mobile radio access penetration. About 80 % of Internet users connected to fixed access networks are also using mobile communications. Therefore, these users are increasingly expecting to get the same services also on mobile terminals. This results in a big market potential for mobile multimedia, which will start with the availability of mobile data systems like GPRS, HSCSD, EDGE and IMT-2000 / UMTS). The success of the "i-mode" Internet service in Japan with more than 7 million subscribers by May 2000 after about one year of service launch shows the potential of data applications. The overall data traffic in terms of bit per second will exceed voice traffic already around 2000 with much higher growth rates than for voice. The growing data and Internet traffic results in dominant packet oriented traffic in the access systems compared to circuit switched traffic. These data services require a high degree of asymmetry between uplink and downlink especially for Internet type services with much higher expected capacity on the downlink, which has already been taken into account by IMT-2000 / UMTS due to the combination of FDD and TDD.

The changed role models for application service providers, content providers, access providers and backbone network providers due to liberalization and privatization of telecommunication companies are driving forces for Internet technology. The Internet protocol (IP) supports fast creation of new applications and services and IP technology reduces the cost of network infrastructure. Already third generation systems are evolving towards all IP-based networks in the Release 2000 of the international body 3GPP (Third Generation Partnership Project) and in further releases of the specification.

There are two migration paths towards all IP-based networks:

- Starting point mobile radio networks: Mobile networks can be migrated by using IP transport in the backbone, supporting data traffic via IP, transporting all user data, including voice, over IP and by terminating IP in the mobile host.
- Starting point Internet: In the case that the Internet is migrated to mobile networks wireless access has to be enabled, the support of user and terminal mobility has to be ensured as well as the support of roaming and handover including the network resource management, and QoS beyond “best effort” has to be provided.

The major necessary improvements are to provide security and AAA (Administration, Authentication and Accounting). In the core network the "stupid network" paradigm is applied. Public and corporate networks are self-similar. They are connected via firewalls. Different access systems can be connected to the IP core network. Mobility management and administration are handled by a server platform outside of the core network.

In addition to the fast growth of Internet usage other technical trends are observed. The first mobile radio terminals were single mode and single band terminals. Today, second generation terminals are implemented for several bands (e.g. combinations of 900, 1800 and 1900 MHz). In the third generation UMTS terminals will be combined, e.g., with GSM. Due to the multiplicity of available standards multimode terminals and finally adaptive terminals based on software defined radio concepts will be introduced. This trend is supported by the increasing available signal processing power, which is expected to grow by a factor of 10 according to a conservative estimate up to a factor of 100 according to Moore's law within the next 10 years. The software defined radio concept will also be applied to base station equipment. Source coding technologies using suitable data compression algorithms reduce the necessary data rate to improve the efficient transport of multimedia data.

Several access technologies are evolving and emerging. Second generation systems are evolving via GPRS, HSCSD and EDGE towards UMTS. In addition, WLAN type systems (Wireless Local Area Network) like HIPERLAN 2 and broadcast systems like DAB (Digital Audio Broadcasting) and DVB-T (Digital Video Broadcasting) are becoming available. For short range connectivity systems like Bluetooth and DECT are being developed. In the fixed access, systems like xDSL and in particular ADSL (Asymmetric Digital Subscriber Line) are increasing the user data rate significantly on the last mile. All these technologies might be part of systems beyond third generation.

The transport capacity of the core network has increased within about 10 years by a factor of $10^6$ with decreasing transmission costs by technology steps from PDH (Plesiochronous Digital Hierarchy), to SDH (Synchronous Digital Hierarchy) and optical communications with WDM (Wavelength Division Multiplexing) and DWDM (Dense Wavelength Division Multiplexing). Therefore, the available transmission speed grows faster than the signal processing power. The core networks are moving towards more transparent transport techniques without any distinction between circuit switched and packet oriented networks to support real-time and non real-time services in the same network. From today's perspective IP is the most promising solution.

Advanced antenna concepts will improve the link quality and channel capacity. These concepts are used to increase the channel capacity of the radio link. Diversity concepts reduce basically the impact of fading due to multipath transmission. Multiple antenna concepts are a further extension of diversity concepts by gaining from uncorrelated multipath transmission channels between the different antenna elements on the base station and the terminal side. The basic idea is to reuse the same frequency band simultaneously for parallel transmission channels by space-time coding to increase the channel capacity. Adaptive antenna concepts improve the link quality by reducing the co-channel interference from different directions and in the more advanced SDMA (spatial division multiple access) concept by reusing the same frequency channels simultaneously for different users at distinct directions. System aspects like common control channels and the signaling concept are an essential part of advanced antenna concepts in order to achieve the possible range extension for the common control channels as for the traffic channels. These are key concepts to use the scarce frequency spectrum as efficient as possible without major impacts on evolving access systems. Concepts as UMTS have already taken into account necessary prerequisites for adaptive antenna concepts. However, an economic implementation of the different RF frontends and the base band signal processing are technical challenges.

Software defined radios are the major technical challenge for the terminal implementation. Such concepts will become feasible with the progress in semiconductor technology and the increasing available signal processing power.

In addition to these evolving and emerging radio access technologies, research on a new radio interface is proposed which should support high mobility and high data rates.

## 2 Adaptive Antenna concepts and key technical characteristics ~~Smart Antenna~~s

*Editor's Note: Consideration should be given to capturing the essence of this section on about one page and retaining the remainder as part of a technical report or other document.*

### 2.1 Introduction

This annex identifies the key Adaptive Antenna concepts and describes their technical characteristics. The traditional approach to the analysis and design of wireless systems has generally been to address antenna systems separately from other key systems aspects, such as:

- Propagation issues
- Interference mitigation techniques
- System organization (Access techniques, Power control, etc)
- Modulation

Adaptive antenna technologies are best implemented with an overall system approach, where all the system components, including the antenna system, are integrated in an optimal way, leading to substantial coverage improvements (e.g. larger coverage area, reduced "holes" in coverage) for each cell, vastly superior mitigation of interference problems, and substantial system capacity improvements.

This annex reviews the various concepts of adaptive antennas, including the concept of "spatial channels", provides a theoretical analysis of the potential of the technology and identifies the key characteristics.

### 2.2 Antennas and Adaptive Antenna concepts

#### 2.2.1 Antenna and coverage

Radio antennas couple more or less efficiently the electromagnetic energy from one medium (space) to another (e.g., wire, coaxial cable, or wave guide). Simple dipole antennas, radiating and receiving equally well in all directions have been used since the early days of wireless communications. Adequate for simple RF environments where no specific knowledge of the user's location is available, this omnidirectional approach scatters signals, reaching target users with only a tiny fraction of the overall energy radiated into the environment (or, conversely, for emissions from the users towards the base station).

Given this limitation, omnidirectional strategies attempt to overcome propagation challenges by simply boosting the power level of the signals. In settings where numerous users (hence, interferers) are relatively close to each other, this makes a bad situation worse in that the vast majority of the RF signal energy becomes a source of potential interference for other users in the same or adjacent cells, rather than increasing the amount of information conveyed by the link.

In uplink applications (user to base station), omnidirectional antennas offer no gain advantage for the signals of served users, limiting the range of the systems. Also, this single element approach has no multi-path mitigation capabilities.

Therefore omnidirectional strategies directly and adversely impact spectral efficiency, limiting frequency reuse.

A single antenna can also be constructed to have certain fixed preferential transmission and reception directions: today many conventional antenna systems split or "sectorize" cells. Sectorized antenna systems take a traditional cell area and subdivide it into "sectors" that are covered using multiple directional antennas looking sited at the base station location. Operationally, each sector is treated as a different cell. Directional antennas have higher gain than omnidirectional antennas, all other things being equal, and hence the range of these sectors is generally greater than that obtained with an omnidirectional antenna. Sectorized cells can improve channel reuse by confining the interference presented by the base station and its users to the rest of the network, and are widely used for this purpose. As many as six sectors per cell have been used in commercial service.

### 2.2.2 Antenna and multipath

In a step towards smarter antennas, i.e. antennas that adapt to the environment, space diversity antenna systems incorporate two antenna elements whose physical separation is used to combat the negative effects of multipath.

Diversity offers an improvement in the effective strength of the received signal by using one of two methods:

- Switched Diversity (SW): Assuming that at least one antenna will be in a favorable location at a given moment, this system continually switches between antennas (connecting each of the receiving channels to the most favorably located antenna) to select the antenna with the maximum signal energy. While reducing signal fading, SW does not increase gain since a single antenna is used at any time, and does not provide interference mitigation.
- Diversity Combining: This approach coherently combines the signals from each antenna to produce gain: Maximal ratio combining systems combine the outputs of all the antennas to maximize the ratio of combined received signal energy to noise.

In contrast to SW systems, diversity combining uses all antenna elements at all times for each user, creating an effective antenna pattern that dynamically adjusts to the propagation environment. Diversity combining is not guaranteed to maximize the gain for any particular user, however. As the algorithms that determine the combining strategy attempt to maximize total signal energy, rather than that of a particular user, the effective antenna pattern may in fact provide peak gain to radiators other than the desired user (e.g. co-channel users in other cells). This is especially true in the high interference environment that are typical of a heavily loaded cellular system.

### 2.2.3 Antenna Systems and Interference

More sophisticated antenna systems can mitigate the other major limiting factor in cellular wireless systems, co-channel interference. For transmission purposes, the objective is to concentrate RF power toward each user of a radio channel only when required, therefore limiting the interference to other users in adjacent cells. For reception, the idea is to provide peak gain in the direction of the desired user while simultaneously limiting sensitivity in the direction of other co-channel users. This assumes an antenna system with instant beam steering capabilities: This can be achieved with phased array technology, in particular with digital beam forming techniques.

In addition, using a larger number of simple antenna elements gives a new dimension to the treatment of diversity as well.

### 2.2.4 Adaptive Antenna Systems

The advent of powerful and low-cost digital signal processors, general-purpose processors and ASICs, as well as the development by several companies and research entities of software-based signal-processing techniques have made advanced adaptive antenna systems a practical reality for cellular communications systems: arrays of multiple antennas, combined with digital beam forming techniques and advanced low cost base-band signal processing open a new and promising area for enhancing wireless communication systems.

Terms commonly used today that embrace various aspects of smart antenna system technology include intelligent antennas, phased arrays, spatial processing, digital beam forming, adaptive antenna systems, etc. Adaptive antenna systems are customarily categorized as either "switched beam" or "adaptive array" systems. However, they both share many hardware characteristics and are distinguished primarily by their adaptive intelligence.

At the heart of an adaptive antenna system is an array of antenna elements (typically 4 to 12), whose inputs are combined to adaptively control signal transmission and reception. Antenna elements can be arranged in linear, circular, planar, or random configurations and are most often installed at the base-station site, although they may also be implemented in the mobile terminal. When an adaptive antenna directs its main lobe with enhanced gain to serve a user in a particular direction, the antenna system side lobes and nulls (or directions of minimal gain) are directed in varying directions from the center of the main lobe. Different switched beam and adaptive smart antenna systems control the lobes and the nulls with varying degrees of accuracy and flexibility. This has direct consequences in term of system performance.

### 2.2.4.1 Switched-Beam Antenna

Switched beam antenna systems form multiple fixed beams with heightened sensitivity in particular directions. These antenna systems detect signal strength, choosing from one of several predetermined, fixed beams, based on weighted combinations of antenna outputs with the greatest output power in the remote user's channel, and switching from one beam to another as the mobile moves through the sector. These choices are driven by RF or base-band digital signal processing techniques. Switched beam systems can be thought of as a "microsectorization" strategy.

### 2.2.4.2 Adaptive Array Antenna

Adaptive antenna technology represents the most advanced approach to date. Using a variety of signal-processing algorithms, an adaptive system effectively identifies and tracks all the relevant signals and interferers present in order to dynamically minimize interference and maximize reception of the signals of interest. In the same manner as a switched-beam system, an adaptive system will attempt to increase gain based on the user's signal as received at the various elements in the array. However, only the adaptive system provides optimal gain while simultaneously mitigating interference. Diversity combining also continuously adapts the antenna pattern in response to the environment. The difference between it and the adaptive antenna method is fundamentally in the richness of the models on which the two systems' processing strategies are based. In a diversity system, the model is simply that there is a single user in the cell on the radio channel of interest. In the adaptive system, the model is extended to include the presence of interferers and, often, temporal history regarding the user's propagation characteristics. With this second model, it is possible to discriminate users from interferers, even at low SINR's, and provide reliable gain and interference mitigation.

The adaptive antenna systems approach to communication between a user and the base-station in effect takes advantage of the spatial dimension, adapting to the RF environment — including the constellation of users and other emitters — as it changes, according to predefined strategies. This approach continuously updates the base station system's radiation and reception patterns, based on changes in both the desired and interfering signals relative configuration. In particular, the ability to efficiently track users through antenna main lobes and interferers through nulls ensures that the link budget is constantly maximized. By implementing the smart antenna strategies digitally, it is possible for the base station to support a separate, tailored, strategy for each active channel in the system via a single array and set of radio electronics.

The difference between the two approaches — adaptive and switched beam — is illustrated in Figure 1, which shows how the adaptive algorithms behave with respect to interferers and the desired signal.

#### 2.2.4.3 Spatial Processing: The Fully Adaptive Approach

Utilizing sophisticated algorithms and powerful processing hardware and microprocessors, “spatial processing” takes the frequency reuse advantage resulting from interference suppression to a new level. In essence, spatial processing dynamically creates a different beam for each user and assigns frequency/channels on an ongoing basis in real time. Spatial processing maximizes the use of multiple antennas to usefully combine signals in space, through methods that transcend the “one user-one beam” methodology.

Depending on the details of the air interface and the service definition, so-called “spatial channels” can be robustly created via spatial processing whereby each conventional temporal channel (e.g. frequency and timeslot or code combination) may be reused within the cell, achieving reuse factors less than one. Figure 2 depicts such a situation for two users. Spatial channels, or intra-cell reuse, are used operationally today in commercial cellular systems in several countries. While the concept of intra-cell reuse may seem unfamiliar, it is readily supported so long as adequate spatial selectivity is available in the distribution and collection of radio energy from the cell. Depending on the air interface, as little as 10 dB of spatial selectivity or isolation for different locations in the cell may be adequate.

## 2.3 Theoretical Analysis of Adaptive Antenna enhancements

### 2.3.1 Introduction

This analysis estimates the maximum capacity or spectral efficiency of a cell as a function of the frequency reuse factor in the network. The “Uplink” or “Reverse Link” Signal to Interference Noise Ratios (SINR) in the cellular network are first calculated via computer simulations that may include empirically derived adaptive antenna processing gains at the base station. (In this analysis user terminals are considered to only have conventional antenna systems). The theoretical capacity is then derived using Shannon’s law, modified to include various “coding gaps”[4].

### 2.3.2 Model definition

#### 2.3.2.1 Methodology

Given a fully loaded network (All communication resources used), and a fixed number of users “N” per base station, for a given allocated network bandwidth “B”, the problem is to select the frequency reuse factor “R”, which will maximize the capacity of the network, hence its spectral efficiency. The trade-off is as follows: The lower the frequency reuse factor, the higher the bandwidth available per user “b”, but the higher the interference per user.

The user’s available bandwidth is:

$$b=B/(NR)$$

[4] Coding Gap is the difference (usually expressed dB relative to SNR) between the operational channel capacity and the Shannon limit (which assumes the use of infinite length block codes). If the Shannon limit is log_2( 1 + SNR ) b/s/Hz and the actual throughput is log_2( 1 + a x SNR ) b/s/Hz, a <= 1 where 'a' is the coding gap.

Following the evaluation of the available SINR after the adaptive antenna processing, Shannon's law gives the user's available capacity:

b x LOG2(1+a **x** SINR(R))

where "a" represents the coding gap (in the range of -3 to -6 dB).

The aggregate cell capacity is then (B/R) x LOG2(1+a x SINR(R)).

and the network spectral efficiency is : η=(1/R) x LOG2(1+a x SINR(R)), usually expressed in Bit/s/Hz /Cell.

The reuse factor which maximizes the total base station capacity, hence the network's system spectral efficiency is shown on the plot of η=function(R,a).

#### 2.3.2.2 The cellular model

The cellular model which has been selected in this analysis is the so called "concentric circular cellular geometry", where all cells have equal areas, and the cell of interest is also circular, located in the center of all surrounding cells (See Rappaport: "Wireless communications") Three tiers are included in the analysis with 8, 16, 24 cells respectively each, as sources of co-channel interference for the central cell.

User terminals are placed uniformly in their respective cells. We assume they are fitted with conventional omni-directional antennas.

#### 2.3.2.3 Propagation model

The interference of the surrounding cells into the cell of interest is evaluated with a typical path loss exponent of 3.5. At this stage, the dispersion in path losses is not taken into account, although it is anticipated to have an impact on the capacity. This impact is more important at high reuse factors, as, with the number of interferers decreasing, averaging effects are reduced.

#### 2.3.2.4 Limitations of the model

The methodology presented above might be improved upon, for instance by adopting different parameter values, e.g. number of array elements, more elaborate propagation models, or more realistic cellular models. The model does not include multipath effects. Unequalized multipath can be approximately considered as reducing the SINR.

The analysis also considers the uplink only. To the extent that downlink SINR's differ from those of the uplink, the analysis should be considered approximate. There are many factors that determine the relative performance of uplink and downlink adaptive antenna processing including the following.

- Air interface specifics, duplexing method in particular (TDD vs. FDD)
- Propagation environment
- Service definitions including data rates, user mobility and so on
- Smart antenna processing algorithms

### 2.3.3 Results and Comparisons

#### 3.2.3.3.1 Case with a single element antenna

A simulation of a single element antenna is performed, to provide a reference for the SINR enhancements provided by Adaptive Antennas. Figure A gives the mean SINR, available at the output of the antenna, as a function of the reuse factor.

The low reuse factor region may correspond to the case of CDMA systems; in this case the SINR is computed before application of the "de-spreading processing gain".

For high reuse factors, (In this context, reuse factors are typically greater than one) the loss dispersion effects mentioned in 3.2.3 may mean that the mean SINR values presented in the plot are optimistic.

#### 3.2.3.3.2 Adaptive Antenna Array with 12 elements

Figure B represents the mean uplink SINR for a 12 elements array adaptive antenna, after processing. The results are obtained through special simulation software, adapted from actual adaptive antenna processing software and system models. This software aims at maximization of the SINR, by increasing the antenna gain for the user of interest while attempting to minimize gain for interfering signals.

#### 2.3.3.3 Network spectral efficiency

The above results are the basis for defining the network spectral efficiency as a function of the reuse factor, for different values of the "coding gap". The results are shown in Figure C.

They show SINR values, after adaptive antenna processing, in terms of spectral efficiency in Bit/s/Hz/Cell, and demonstrate the considerable potential of adaptive antennas.

The analysis shows that a network spectral efficiency of 4 to 6 Bit/s/Hz/Cell is achievable. In contrast, most 2G cellular systems today operate at a spectral efficiency of approximately 0.1-0.2 Bit/s/Hz/Cell.

#### 2.3.3.4 System performance

Adaptive Antennas have been successfully applied by manufacturers and design houses in the USA, Europe and Japan to several existing air-interfaces and deployed commercially, as well as applied to air interfaces in development. (Annex 2 Refers)

Published and unpublished results from system deployments, field-testing or desk system studies demonstrate that, although most of these (circuit-switched) systems were developed without any consideration being given to adaptive antennas, if not armed with features that are antithetical with adaptive antenna inclusion, substantial overall performance improvements can nonetheless be obtained.

This analysis shows that if Adaptive Antenna system requirements are integrated from the outset in the overall creation of future air interfaces, substantial additional performance improvements and overall higher spectral efficiencies can be obtained.

This analysis also alludes that in the case of existing packet-switched systems, it is difficult to make general statements on the performance improvements that might be derived from the inclusion of adaptive antennas. Suffice it to say that, in order to meet the performance benchmarks yielded by the model, such systems must fundamentally be designed from the outset with due consideration given to adaptive antenna requirements.

*[Insert Figure A from Document 8F/201-E here.]*

FIGURE A

**SINR versus Reuse Factor (1 antenna)**

*[Insert Figure B from Document 8F/201-E here.]*

FIGURE B

**SINR versus Reuse factor for a 12 element array smart antenna**

*[Insert Figure C from Document 8F/201-E here.]*

FIGURE C

**Spectral Efficiency for Adaptive Antenna versus Reuse Factor**
**For 4 and 6 dB Coding Gap**

## 2.4 Key Technical Characteristics

It has been emphasized above that the implementation of an adaptive antenna system is a complex system problem, involving trade-offs amongst many parameters. At this stage, the following aspects have been identified as key technical characteristics from an overall performance standpoint, although implementation aspects should be considered as key parameters as well:

- Number of antenna elements in the array.
- Services aspects
  - Voice circuit versus data packet.
  - Wideband or narrowband services.
- System aspects:
  - FDD versus TDD.
  - Access techniques: CDMA versus TDMA.
  - Modulation: Multi-carrier versus single Carrier
  - System organization:
    - Protocols
    - Power control
    - Pilot signals
    - Synchronization
    - Training information

   - Radio propagation characteristics
   - Use of other interference mitigation techniques
- Design flexibility: Add-on feature or new overall system design.

### 2.4.1 Number of array elements

The number of elements in antenna array is a fundamental design parameter, as it defines the degrees of freedom available to the system in creating optimal patterns, and the additional gain the array will provide. This parameter is typically in the 4 to 12 range, the upper-limit being dictated on one hand by economical considerations, and on the other hand by practical considerations regarding implementation, installation or increasingly, environmental issues.

The achievable improvement in system spectral efficiency increases with the number of elements in the array.

### 2.4.2 FDD versus TDD systems

Adaptive antenna systems generally discriminate and identify emitters based on the relative phases and amplitudes of a given emitter's signal at the various elements in the array. This collection of complex numbers is called the "spatial signature" of the emitter. On the uplink, the signature is directly measured by the base station, which develops its subsequent processing strategy for the uplink signals. On the downlink, however, in the absence of any additional information regarding the propagation channel from the base station to the user, an estimate or extrapolation of the downlink signature must be generated. Since the estimate of the downlink signature is less exact than that of the uplink signature, downlink adaptive antenna performance tends to be less than that on the uplink. Here, there is a clear-cut difference between FDD and TDD systems:

- Due to the frequency separation in up and down links, FDD systems exhibit uplink and downlink propagation characteristics that are not well correlated on a short-term basis, whereas in TDD systems the uplink and downlink channels can be considered more reciprocal.
- Independent of the decorrelation issue mentioned above, the fact that the uplink and downlink are at different frequencies for an FDD system introduces the additional complexities of frequency scaling and more elaborate equipment calibration to map uplink signatures to downlink signatures.

The practical effect is that the capacity, and to a lesser extent downlink gain, improvements provided by adaptive antennas in FDD systems are generally less than those provided in TDD systems due to the greater relative mismatch of uplink and downlink performance in the former. It should be stressed, however, that significant gains for FDD systems are realizable.

### 2.4.3 Service aspects

The type of service to be provided also impacts on the downlink extrapolation problem mentioned above: In a circuit-switched system, there is some short-term persistence in the way the system resources are utilized. Thus, there is the same persistence in the interference environment, and some correlation between uplink and downlink interference characteristics. Adaptive antenna systems can exploit this correlation of the interference environment in performing their downlink processing. In a packet-switched system, where the uplink and downlink interference environments may be quite different and where user transmissions are bursty, the correlation between the uplink and downlink interference environments may be quite different.

Therefore adaptive antenna techniques will behave differently in packet data systems and voice circuit systems.

#### 2.4.4 Design flexibility

The benefits of adaptive antenna technologies will also vary depending on whether they are implemented as an add-on (or appliqué) to an existing system (designed without consideration to adaptive antenna issues) – e.g. that may be the case when backward compatibility requirements prevent any modification of the Air Interface – or whether they are incorporated from the outset in an air interface design.

#### 2.4.5 Propagation environment

The algorithms used in adaptive antennas may also help handle some multi-path effects by taking advantage of space diversity, and in fact adaptive antennas mitigate multipath problems, although achievable performance will ultimately depend on the complexity of the radio environment.

The focused reception (transmission) patterns generated by the array tend to reduce the amount of multipath that must be compensated for in the base station (terminal) receivers, reducing the complexity of temporal equalization through "spatial equalization." This property will be increasingly valuable as systems evolve towards higher symbol rates and higher order modulation schemes. On the other hand, this spatial equalization process consumes some of the degrees of freedom in the effective pattern generation, however, which can reduce the level of interference mitigation performance.

#### 2.4.6 Access techniques

Two main access techniques need be considered: CDMA and FDMA. The selection of one or the other may have an influence on the performance of the adaptive antenna system, all else being equal. Intuitively, CDMA lends itself better to combating interference, and this can be taken into account in the adaptive antenna algorithms design strategy. However, in a CDMA system which transmits many channels in parallel over a larger bandwidth, each user signal is confronted with a large number of interferers, which the antenna system cannot individually reduce to zero: Thus, an interference-nulling strategy is not appropriate and other beam forming criteria must be implemented.

#### 2.4.7 Other system considerations

offs. In addition to those mentioned above, the following points also deserve due consideration:

- Factors having an impact on the downlink signature de-correlation with respect to the uplink signature:
  - Frame length in TDD
  - Duplexing distance and uplink/downlink delay in FDD
  - Modulation bandwidth
  - Interaction with power control functions
  - User mobility
- Factors having an impact on algorithm complexity:
  - Modulation and equalization requirements
  - Service requirements (Packet versus Circuit)
  - Protocols design for Packet systems

- Factors having an impact on efficiency trade-offs
  - Use of other interference mitigation techniques
  - Frequency planning and/or frequency reuse policy
  - System functions which cannot use spatial channels:
    - Broadcast functions
    - Paging functions

Finally, the preceding analysis focused on adaptive antennas implemented solely at the base station. If adaptive antennas were also implemented at the subscriber terminal, significant additional benefits accrue, even with two-element arrays. The major challenges here are ones of form factor and power consumption at the terminals.

*[Insert Figure 1 from Document 8F/201-E here.]*

FIGURE 1

**Difference between switched beam and adaptive beam**

*[Insert Figure 2 from Document 8F/201-E here.]*

FIGURE 2

**A two user spatial channels strategy, reuse = 0.5**

## 3 Software Defined Radios

*Editor's note: Consideration should be given to moving this material to Informative Attachment 1.4 in the section on Software Defined Radios.*

### 3.1 Mapping requirements from chapter 7.1 and chapter 5.3.1.1 to technologies

Analysis of the needs and regulatory issues reveals a mapping of requirements and constraints onto a set of key system support functions and enabling technologies. These fall into three distinct groups:

- Creation and provisioning of services over converging networks and different radio access modes
- User environment management and distributed processing framework supported by appropriate middleware(s)
- Radio reconfiguration control

### 3.2 Creation and provisioning of services over converging networks and different radio access modes

A key enabler for reconfigurable radio systems is the fast creation and provision of scalable services, developed independently of, and adaptive to the underlying network technologies, environment and traffic conditions, allows the convergence of fixed, wireless and broadcast networks. In conjunction with an appropriate management framework (distributed processing environment for reconfigurable terminals facilitated by e.g. a set of middleware) including capability negotiation and secure software download for reconfigurable terminals, services may be provisioned by adaptation to available resources, considering the terminal itself as a processing resource. This scheme requires the existence of a service description framework, possibly describing services in terms of reusable components and open interfaces, and a distributed processing control framework. The 'Open Interface Service Provision (OISP) is an example of such a scheme being developed under the 3G Partnership Programme (3GPP). A common terminal execution environment for *applications* namely MExE (Mobile Execution Environment), supports WAP, personal-JAVA and CLDC/MIDP Java environments independent of the access scheme (2G, 3G, cordless, wired), and is under development in 3GPP TSG-T2. Common to each application execution environment is a terminal capability negotiation mechanism and defined security domains through which applications may be downloaded and executed with appropriate access to terminal resources. Research work must investigate extensions to the MExE environment required to support software download of components and parameters *below* the application layer.

- Service creation and service mobility
- Secure software download
- Scalable service provision with scalable QoS
- Common execution environment
- Consolidated billing mechanism

### 3.3 User Environment Management and Distributed Processing Framework

These software concepts essentially provide the mechanisms to support requirements for user friendliness, transparent reconfiguration and distributed application processing. In computer networks, object-oriented technologies for distributed systems provide scalability and modularity, resulting in efficient software provisioning, faster deployment and bug fixing, higher flexibility and therefore improved cost efficiency. A framework is required to coordinate and manage communications and interworking within the distributed, object oriented environment. With the continuing convergence of computer and mobile communications technologies, such a framework could supply much of the support needed to realise the user-friendly, ubiquitous environment demanded by the future user. QoS management, reliability, mobility, security, radio resource management, distributed configuration management and user-preference agents may be considered as independent distributed objects operating within the overall network concept. The distributed run time system must support following functions:

- Secure end-to-end configuration negotiation between (distributed) parties with different domains of responsibility (user, service provider, network operator, manufacturer)
- Intelligent configuration (creation/update and secure management) of applications according to terminal and service capabilities and user preferences
- Secure software download
- Distributed processing for applications and configuration management

A mobile framework for distributed processing could then be viewed as a virtual backplane supporting objects distributed between the terminal, Node B and RNC. It would be able to handle facets associated with a radio link between terminal-resident and network-resident objects, namely temporary disconnections, multiple simultaneous connections, terminal mobility, migration of objects between terminal and network via download (statically or dynamically, i.e. during run time), and should potentially support functionality such as:

- Maintenance of QoS for real-time applications
- Safe interworking between disparate software components from different sources
- Adaptation of applications to dynamic availability of resources (processing, bearer services)
- Managing handoff between air-interfaces where required services are only available to certain air interfaces
- Concurrency and persistence, allowing the implementation of distributed processing and for the support of seamless handoff between different radio access schemes

The virtual backplane concept may be schematically described as below, where objects for terminal management and user applications can migrate during run time. With migration of objects, mobile agents can be realised.

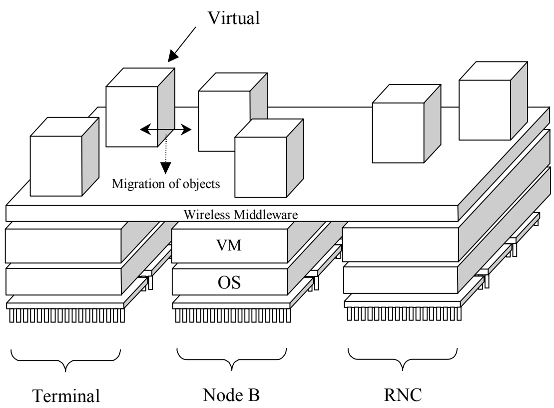


FIGURE 2

**Virtual Backplane in a Distributed Processing Environment**

## 3.4 Radio Reconfiguration Control

The functions described in previous section represent the key enablers for reconfigurable terminals to provide the connectivity, mobility, reliability, security and QoS required to access the potential of the evolved network scenario and thus to deliver the user requirements. Some terminal-centric solutions exist today and represent the state-of-the-art, however maximum benefit requires terminal/network cooperation and this is a central theme of system aspects research. Novel solutions will be proposed and evaluated in terms of complexity, performance, overhead, tradeoff and feasibility through development of system models and simulation. In particular, the reconfiguration control has to reflect following functions:

- Radio access mode identification, blind and assisted
- Radio access mode switching management
- Simultaneous connection to multiple services
- Secure software download including authentication, hierarchical capability exchange and integrity assurance
- Efficient algorithms to realise flexible, robust radio access schemes

- Flexible, reconfigurable terminal/basestation software and hardware architectures

### 3.5 Constraining Considerations

The concept of reconfigurable mobile communications by its very nature implies ever increasing flexibility, resulting in a potential system management nightmare. Research activities must constrain its research by careful consideration of realistic scenarios and constraints, with particular emphasis on:

- Regulatory and system integrity considerations
- Privacy, anti-trust issues and security functions for reliable download
- Complexity tradeoffs
- Feasibility of migration from existing legacy solutions and implementations

These may lead to considerations such as:

- Software download of radio-specific software (baseband, radio protocol stack objects, parameters) will be limited to manufacturer approved builds downloaded from a manufacturer's secure server to protect manufacturer's regulatory liability for system integrity;
- Terminal resource sharing between application and radio-specific software will be feasible only if terminal resources used by radio control software are adequately protected;
- Software updates not specifically requested by the user may adversely modify terminal behaviour due to incompatibility with other installed software
- Anti-trust protection: Transparent introduction of software may hide or disable functions provided by a competitors application;
- Use of intelligent user preference establishment and maintenance schemes to customise the terminal's behaviour must be secure such that user profile data is not accessible to untrusted third parties
- Volume of downloadable software and over-air service negotiation for reconfiguration must be managed to avoid network impairment
- Reconfiguration mechanisms must be backward compatible with existing radio access standards

Regarding consideration of a distributed processing environment to support reconfiguration management aspects, the cost functions are the additional terminal resources (processing power, memory, IO) and over-the-air communication overhead (throughput, delay). Reserach will identify the framework functionality needed to support the key reconfigurable terminal system technologies, estimate key tradeoffs and examine feasibility.

Research for reconfigurable equipment must concentrate on following topics:

## TABLE 2

## **User Assessment, System Support Research, Enabling Technologies and Algorithmic Research**

| | |
|---|---|
| **User Assessment** | **Determination of lead users who have high demands on services and QoS.**<br>**Systematic study of these lead user activities and cost-benefit relationships, via focus group discussions, operator interviews and simulated application demonstrations will define a set of compelling user scenarios which will drive the technology research. This will be augmented by a wider study of regulatory issues and constraining factors.** |
| **System Support Research** | Following a detailed state-of-the-art study, research will be focussed on:<br>**Advanced spectrum allocation and sharing techniques** to maximise spectral efficiency based on deregulated spectrum access defined jointly by industry and regulations.<br>**Vertical Handover** between different air interfaces require radio access mode identification, monitoring and switching: Determining the existence and availability of alternative radio access modes by pilot, assisted or blind methods. Examining the criteria, QoS measurements and algorithms involved in and making a decision to switch radio access modes, and the support and signalling required to execute the switch. Understanding the network/terminal cooperation, middleware and protocols required to realise 'soft' inter-mode handoff, using switching between 3G modes and HIPERLAN2 as a test case. A system focus effort will examine the need for system frameworks and middleware to support technologies to be developed.<br>**Configuration management** of terminals: Considering how a user terminal may be reconfigured, three basic variations of reconfiguration are identified, ranging from Static Reconfigurability = configure equipment capability 'off-line' e.g. at supply, or by smartcard. Pseudo-static Reconfigurability = reconfigure equipment capability over-the-air, but leave unchanged whilst it is in-call or in-session. Dynamic Reconfigurability = auto-reconfigure equipment capability whilst in-call or in-session.<br>**Software download** by taking into account security, regulatory, configuration, capability and resource management considerations regarding download of radio-specific, service-specific and application software or parameters. The two promising candidate schemes of cooperative mechanism for download service providers are broadcast download and distributed download (possible via many paths to the terminals). Traffic models for download scenarios must be agreed between manufacturers and operators to assess the impact on spectral efficiency.<br>Evolution of the **type approval** process to handle radio reconfiguration, and extensions to standards to provide a framework to realise the potential benefits (eg extensions to 3GPP-MExE to allow download of radio software components and parameters below the application layer).<br>The **impact on the network** when managing composite multimode and pure software defined terminals. |
| **Enabling Technologies and Algorithmic Research** | Research into underlying terminal technologies must focus on:<br>Analogue signal processing transceiver architectures: examining system requirements and constraints, proposing and evaluating performance of architectural and derived component solutions. Issues include linearity and efficiency demands on power amplifiers, evaluation of tuneable channel pre-selection filtering schemes, signal cancellation, digital conversion, linearity enhancements and digital control techniques. An assessment of analogue signal processing impact based on the need for simultaneous service connections will be undertaken.<br>Proposal, evaluation and performance analysis of a digital signal processing architecture supporting a reconfigurable object-oriented analysis of the physical layer processing. Reconfiguration by parameter download and incremental download of classes to support the modified access mode will be examined. Architectural support entities will be proposed (eg. class library, reconfiguration management and terminal |

| | |
|---|---|
| | management entities).<br>Development of transceiver algorithms applicable to a) scalable spectrum access and b) power-efficient throughput control adaptive to instantaneous channel conditions., Includes: analysis of a slow frequency hopping multicarrier DS-CDMA scheme including synchronisation aspects and multi-user detection analysis, SINR-based adaptive rate transmission schemes, space-time coding and beamforming/antenna array algorithms in conjunction with Turbo equalisation. Such a scheme has compatibility with 2G, 3G, BRAN and unlicensed schemes, allowing users to exploit the whole system bandwidth and to efficiently utilise frequency resources.<br>Power management will be investigated at both system and component levels. System issues relate to QoS and mode establishment using power budget and remaining power as criteria.<br>Scalable video coding: performance of the H.263+ scalable video coding scheme under dynamic channel bandwidth variations, and object-based scalability in MPEG4 will be assessed. Wavelet filter techniques for scalable image coding will be explored and evaluated against metrics defined in the user requirements analysis. |

## 4 High packet rate nodes

## 5 Consideration on Asymmetry

### 5.1 TDD asymmetry

### 5.2 Modulation asymmetry

### 5.3 Block asymmetry

## 6 Multi-mode technologies, supporting existing 2G, 3G systems

## 7 Technologies for improving bandwidth efficiency

– Frequency band sharing techniques
– Interference reduction technology in unlicensed bands
– Smart antenna, Diversity technology
– Coding technology, Space Time Code
– Adaptive Modulation, OFDM, Multi Carrier Modulation

## 8 Internet technologies

– Routing technology, which supports mobility
– Real time service and guaranteed QoS
– Multicast technology
– Design technology for Protocol, suitable for wireless network (e.g.: Wireless IP, Wireless TCP)
– Security technology

## 9 General Requirements of IP based RAN

### 9.1 Wireless Access Technology Independence

- IP based RAN shall at least support the current 2G and 3G radio technologies such as W-CDMA and cdma2000. This requirement shall be based on the support of the complete backward compatibility and inter-operability. This requirement also makes sure that IP based RAN architecture supporting UTRA can accommodate IP based RAN architecture supporting cdma2000 just by replacing the radio-specific function from UTRA to IP based cdma2000.
- IP based RAN architecture may be flexible to support another non-cellular wireless technology, e.g., Wireless LAN and Bluetooth. This requirement also is based on the flexible architecture to support the Radio-specific function with Plug and Play operation.
- IP based RAN shall support inter-working and inter-operation to support the handoff among different wireless access technologies.

### 9.2 Backward Compatibility

- IP based RAN architecture and associate protocol set shall support the backward compatibility with the current RAN architecture from the ground up.
- From the service perspective, no service and performance degradation are expected in IP based RAN comparing to the current RAN architecture. This requirement shall need some criteria to verify the backward compatibility.
- IP based RAN architecture and associate protocol set shall provide at least the equivalent functionality to the current RAN architectures. The main changes in IP based RAN architecture comparing to the current RAN architecture shall be easily identified.

### 9.3 Interoperability with Legacy (2G/3G) Networks and Mobile Terminals

- IP based RAN architecture shall support interoperability between current 2G/3G Core Network (including GSM MAP, ANSI-41 Core Network) and IP based RAN.
- IP based RAN architecture shall support interoperability between current 2G/3G radio access networks and IP based RAN.
- IP based RAN architecture shall also provide support for legacy (2G/3G) mobile terminals.

### 9.4 Forward Compatibility

- IP based RAN architecture and associate protocol set shall allow the forward compatibility with the architecture accommodating the new radio technologies.
- IP based RAN architecture shall easily accommodate any change to be expected by introducing new services (e.g., IP broadcast/multicast services).

### 9.5 Interoperability with All IP Network and IP based Mobile Terminals

- IP based RAN architecture shall support the interoperability between the All IP Core Network and IP based RAN.
- IP based RAN architecture shall support the interoperability between the next generation following 2G/3G radio access networks and IP based RAN.
- IP based RAN architecture shall also provide support for IP enabled mobile terminals.

## 9.6 Layered Independent Architecture

- IP based RAN architecture shall support the layered architecture.
- IP based RAN architecture shall support the separation among the user plane function, the control plane function, and the transport plane function.

## 9.7 Open Interface Support

- IP based RAN architecture shall support open interfaces between any network entities in IP based RAN that may be implemented by operators/ISPs and manufactures as separate systems, sub-systems, or network entities.
- IETF protocols shall be considered and adopted in these open interfaces wherever possible. For example, Mobile IP mechanism can be another alternative for IP mobility in the RAN.

## 9.8 QoS Support

- IP based RAN architecture shall support the means to enable end-to-end QoS at least within RAN scope.
- IP based RAN architecture shall satisfy the Policy based QoS architecture. This requirement can raise the issue, where the Policy Enforcement Point and the Policy Decision Point are.
- The resolution of QoS in IP based RAN shall be consistent with the ETE QoS on the Core Network level.
- IP based RAN architecture should be capable of simultaneously supporting multiple levels of static QoS (negotiation of parameters before the session setup) as well as dynamic QoS (negotiation of parameters while the session is in progress) including in handoff scenarios.
- IP based RAN architecture shall support the QoS enabled routing/handoff procedure. That is to say, the best selection of the routing path/handoff path satisfying the QoS required by the user shall be possible.
- IP based RAN architecture shall support the configuration with load balancing for supporting the different level QoS requirement per user.
- IP based RAN architecture shall support IPv6 enabled QoS resolutions.
- IP based RAN architecture may support IPv4 enabled QoS resolutions.

## 9.9 IP Transport

- IP based RAN architecture shall transport bearer and control/signalling traffic based on IP technology.
- IP transport in the RAN shall be independent of the L1, L2 technology.
- IP based RAN architecture shall support IPv6/Ipv4 addressing mechanism.

## 9.10 Distributed Dynamic Configuration

- IP based RAN architecture shall support the multiple dynamic configuration between functional entities. For example, the Node B functionality can select an appropriate RNC functionality for satisfying the QoS and the robustness (non-drop) during the call.
- IP based RAN architecture shall support the distributed radio control and bearer control functions.

- IP based RAN architecture shall support the distribution of cells dependent radio and bearer control functions towards the radio access points.

## 9.11 Radio Resource Management

- IP based RAN architecture shall support the efficient radio resource management (allocation, maintenance, and release) in order to satisfy the QoS required by the user and the Policy required by the operator.
- IP based RAN architecture shall support the function to optimise and negotiate the radio resource among the different wireless access technologies that are supported.

## 9.12 Performance

- The performances in IP based RAN architecture regarding to link utilization, QoS, call drop rate, easy handoff, and so on shall be equal to or greater than those in the current RAN architecture.
- IP based RAN architecture shall support increases in capacity without architectural impact.

## 9.13 Scaleable Architecture

- IP based RAN architecture shall provide network operators the ability to expand specific RAN function entities independently of other entities.
- IP based RAN architecture shall allow network operators to gradually deploy network entities and expand their networks.

## 9.14 Security

- IP based RAN architecture shall provide functions to protect its network resources and traffic from unauthorised access.
- IP based RAN architecture shall handle multiple radio link authentication protocols (e.g., CAVE for IS-95, A5/1 for GSM).
- IP based RAN architecture shall allow AAA to be present in the RAN or in the core network for access authentication, authorization.

## ~~3.9 IP Broadband Wireless Access~~

### ~~3.9.1 Breaking the Wireless Access Bottleneck: IP Broadband Wireless Access~~

# 10 HAPS

High Altitude Platform Station, or HAPS, is a new technology that can revolutionize the wireless industry. A HAPS platform will consist of an extremely strong, lightweight, multi-layer skin containing buoyant helium, a station keeping system consisting of GPS and an advanced propulsion system, a telecommunications payload, thin film amorphous silicon solar panels for daytime power, and regenerative fuel cells for nighttime power. The enabling technologies are high efficiency solar cells and fuel cells that are both lightweight and durable, high strength ultra thin fiber and helium impermeable seal, thermal and pressure control/management techniques, as well as advanced phased antenna array and MMIC (microwave monolithic integrated circuit) technologies.

A HAPS is designed with a lifespan of 5 to 10 years. Service beyond this term is limited by the gradual degradation of solar and fuel cells, structural fatigue and the decomposition of gas-storage modules. Ongoing advances in high strength, light-weight, UV-resistant composite materials, fuel cells, solar cells, and compact, high speed semiconductor device will likely extend the lifespan of second generation HAPSs.

### 10.1 RF MEMS as an enabling technology for the future terminal

Future personal communications systems will require very light weight, low power consumption, and small size. The requirements of IMT-2000 terminal such as small size, multi frequency bands, multi-mode and functional complexity demand the use of highly integrated RF front-ends and a compact system on chip solution. Despite many years of research, widely used discrete passive components based on electronic solutions cannot easily satisfy the above requirements of the future IMT-2000 terminal.

RF MEMS (Micro-Electro-Mechanical Systems) are integrated micro devices (or systems) combining electronical and mechanical components fabricated using an IC (Integrated Circuit) compatible batch-processing technique. This technology can yield small size, light weight, low power and high performance to replace discrete passive RF components such as VCO, IF, RF filters and duplexer. System on chip using this technology can reduce the actual implementation size by 1/10.

As the users of the future wireless communication systems continually push handset manufacturers to add more functionalities, the manufacturers are confronted with trade-offs among cost, size, power and packaging constraints. It is anticipated that RF MEMS emerges as a breakthrough technology to satisfy with these constraints of future terminal. The commercialisation of RF MEMS for the future terminal will be within the next 5 years.

## ANNEX 7

**Considerations on System Management and Security**

- System Management and Security (description of system management, security and interoperation with external systems e.g. broadcasting etc)

## ANNEX 8

**Developing Country Requirements`**

**(May be more appropriate to incorporate instead in the Developing Country Handbook?)**

### 1 Developing Country

*Editor's Note: The following recommendation and Handbook should be utilized in the development on the subject area of Developing Country (M.819-2).*

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