RECOMMENDATION ITU-R M.1035

FRAMEWORK FOR THE RADIO INTERFACE(S) AND RADIO SUB-SYSTEM FUNCTIONALITY FOR INTERNATIONAL MOBILE TELECOMMUNICATIONS-2000 (IMT-2000)

(Question ITU-R 39/8)

(1994)

The ITU Radiocommunication Assembly,

recommends

that the elements addressed in this Recommendation be considered as the initial framework of concepts and principles regarding the International Mobile Telecommunications-2000 (IMT-2000) radio interface(s) and radio sub-system functionality.

In particular the Recommendation addresses three key factors:

– the concept of radio interface(s) based on core elements common to all interfaces and extensions to these elements;

– the establishment of transmission independent and transmission dependent aspects of the interface(s);

– the adoption of a flexible layered cell structure.

The Recommendation refines the concept of IMT-2000 and will be used to guide future Recommendations that will specify IMT-2000 in more detail.

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1. Introduction

International Mobile Telecommunications-2000 (IMT-2000) are third generation mobile systems (TGMS) which are scheduled to start service around the year 2000 subject to market considerations. They will provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks (e.g. PSTN/ISDN), and to other services which are specific to mobile users.

A range of mobile terminal types is encompassed, linking to terrestrial and/or satellite based networks, and the terminals may be designed for mobile or fixed use.

Key features of IMT-2000 are:

– high degree of commonality of design worldwide,

– compatibility of services within IMT-2000 and with the fixed networks,

– high quality,

– use of a small pocket-terminal with worldwide roaming capability.

IMT-2000 are defined by a set of interdependent ITU Recommendations of which this one is a member.

This Recommendation forms part of the process of specifying the radio interface(s) of IMT-2000. IMT-2000 will operate in the worldwide bands identified by the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) (1 885-2 025 and 2 110-2 200 MHz, with the satellite component limited to 1 980-2 010 and 2 170-2 200 MHz).

The subject matter of IMT-2000 is complex and its representation in the form of Recommendations is evolving. To maintain the pace of progress on the subject it is necessary to produce a sequence of Recommendations on a variety of aspects. The Recommendations strive to avoid apparent conflicts between themselves. Future Recommendations, or revisions, will be used to resolve any discrepancies.

2. Scope

The purpose of this Recommendation is to present an overview of the radio subsystem for IMT-2000 and give guidelines for the development of the structure of the radio sub-system. The radio sub-system includes the functionalities needed to provide IMT-2000 services over a radio interface(s) to mobile terminals in all IMT-2000 operating environments, as defined in Recommendation ITU-R M.1034 on Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000).

The Recommendation provides a high-level definition of logical elements and functionalities within the radio sub-system, including the radio interface, channel structure, link control and radio system management functions.

In addition, this Recommendation identifies areas which are to be specified in detail in subsequent Recommendations.

3. Structure of the Recommendation

In § 4 issues relating to other Recommendations are discussed. Section 5 addresses definitions. Section 6 states the considerations that have been taken into account in the production of this Recommendation. In § 7 the radio interface(s) is defined and characterised. Section 8 outlines the protocol structure. Section 9 outlines the channel structure and multiplexing. Section 10 outlines the cellular structure and related issues. Section 11 outlines the link control and system management functions, which include link quality measurement, channel selection/assignment, handover and mobility supporting functions. Finally, Section 12 is a collection of specific issues that need to be addressed as a part of the radio sub-system specification in order to meet the system performance requirements.

4. Related documents

- Recommendation ITU-R M.687: International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.816: Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.817: International Mobile Telecommunications-2000 (IMT-2000). *Network architectures*
- Recommendation ITU-R M.818: Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.819: International Mobile Telecommunications-2000 (IMT-2000) for developing countries
- Recommendation ITU-R M.1034: Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.1036: Spectrum considerations for implementation of International Mobile Telecommunications-2000 (IMT-2000) in the bands 1 885-2 025 MHz and 2 110-2 200 MHz
- Recommendation ITU-R M.1079: Speech and voice band data performance requirements for International Mobile Telecommunications-2000 (IMT-2000)
- Recommendation ITU-R M.1225: Guidelines for evaluation of radio transmission technologies for IMT-2000

5. Definitions

The terms used in this Recommendation are consistent with definitions used in other ITU-R Recommendations regarding IMT-2000.

6. Considerations

In the development of this Recommendation the following considerations, *inter alia*, have been taken into account:

a) the relevant ITU-R and ITU-T Recommendations and ongoing studies;

b) that system compatibility is necessary for international operation, and that commonality is desirable in any event to ensure that the overall cost per mobile user is significantly less than it is with present systems;

c) the need for a flexible system structure able to match network investment to the revenue growth, to adapt readily to environmental factors and to respond to new developments without restricting innovation;

d) the need for mobile stations (including those with satellite capability) to roam between mobile telecommunication networks in different countries;

e) that standardised radio interface(s) would facilitate the roaming of mobile stations between networks;

f) that satellite operation within IMT-2000 holds the possibility of significantly enhancing the overall coverage and attractiveness of the services;

g) the increasing importance of spectrum efficiency and the need for ease of spectrum management, both within and between countries/regions;

h) the radio interface(s) should be designed with scope for innovation, for example the later inclusion of services and features not envisaged yet.

7. Radio interface(s) definition and characteristics

The IMT-2000 radio interface is the means of realising the wireless electromagnetic interconnection between an IMT-2000 mobile station (or mobile earth station) and an IMT-2000 base station (or space station).

The IMT-2000 radio interface specification consists of a statement of the form and content of the signals transmitted from stations. The specification contains the definition of functional characteristics, common radio (physical) interconnection characteristics, signal characteristics, and other characteristics, as appropriate.

It should be noted that the satellite operating characteristics have many differences to the terrestrial operating characteristics. See § 10.1 for details on the satellite operating characteristics.

7.1 Commonality of the radio interface(s)

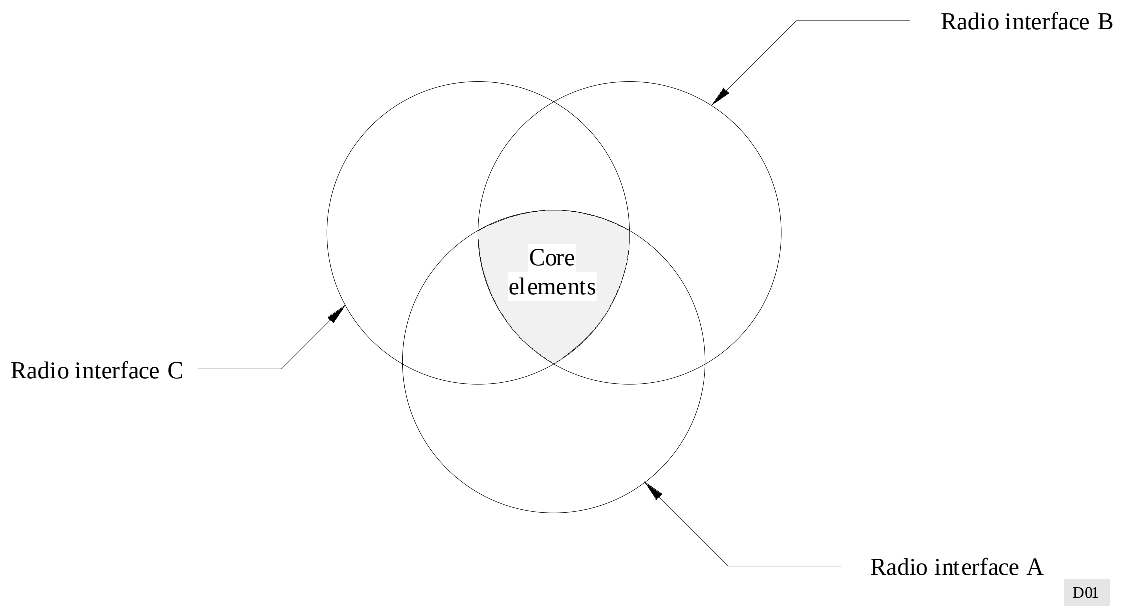
IMT-2000 may need to use more than one radio interface in order to meet various operating environment or application needs. However, IMT-2000 users may want the ability to use one terminal to access a given set of services in more than one operating environment.

It is desirable to minimise the number of radio interfaces. If multiple interfaces are needed, the degree of commonality between these interfaces should be maximised. Minimising the number of radio interfaces and maximising commonality between different radio interfaces would facilitate inter-operability while minimising cost. Maximising commonality would also facilitate the incorporation of different radio interfaces into a single portable terminal at a reasonable cost.

Commonality is defined as a common group of core elements that may or may not comprise a complete radio interface (see Fig. 1).

FIGURE 1

Core elements concept



The core elements concept should facilitate the definition of a universal platform that can be easily adapted to the various environment and service usage requirements. Manufacturers would benefit from such design if, due to the algorithmic flexibility inherent in digital systems of modular design, the adaptation capabilities are implemented as “software” reconfigurations of various modules in the transmission chain.

It is important that IMT-2000 support terminal mobility where the same terminal can be used in all environments if desired. This means that it must be possible to move between the different environments with the same terminal. It is impractical to provide terminal mobility for all possible services in all environments; therefore, a set of basic service functions must be defined for which full terminal mobility in all radio operating environments is desired.

A target for the IMT-2000 radio interface(s) is to support the possibility of using one low cost hand-portable terminal in a large number of operating environments with access to at least a minimum set of all services.

Restrictions in terms of bandwidth, range, and complexity imply that it may not be feasible for a single radio interface to support the use of an IMT-2000 terminal in all operating environments with access to all services. In this case the number of different radio interfaces should be made as small as possible with the restriction of not imposing too high complexity.

Radio interface(s) should be developed using layered and building block approaches in order to maximise commonality and allow flexibility. Radio interface specifications should allow for the use of standardised extensions to a set of interface core elements to facilitate changes in service based on users' needs, radio environments, and other factors. The use of these extensions should also facilitate the development of new services and capabilities.

7.2 Layered approach to commonality

A layered approach is used to clearly define the interface structure and protocols required to support telecommunication services. Additional advantages are identified by employing a layered approach; examples include the inter-system availability of software packages developed for signalling/communication layers of specific systems. Another advantage identified in mobile radio communication is the ability to separate radio interface functions as transmission independent and transmission dependent. This separation may require a sub-layered structure. The set of transmission independent functions should be maximised to facilitate interoperability across different radio interfaces. For example:

a) Transmission independent:

- application protocol,
- call control,
- identity, validation and confidentiality,
- registration and location control,
- acknowledgement control and error recovery procedure in flow control,
- maintenance and configuration,
- logical channel structure and multiplexing.

b) Transmission dependent:

- RF functionalities,
- radio resource management,
- error detection/correction.

A common protocol can be applied to the transmission independent part for all radio interfaces. The building block approach and the choice of an appropriate set of interface core elements would be used to maximise commonality. Additional discussion of protocol layering is contained in § 8.

7.3 Building block approach to commonality

The set of the basic building blocks that may make up the transmission dependent portion of a low layer radio interface include the following:

- transmission multiplexing,
- transmission frame structure,
- duplexing method,
- RF channel bandwidth choice,

– source coder bit-rate and algorithm selection,

– channel coding and interleaving,

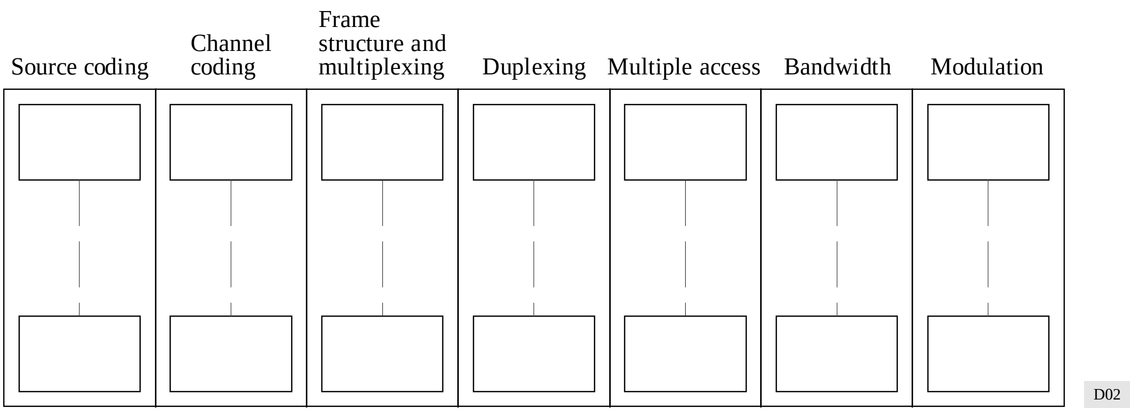
– multiple access method,

– modulation scheme.

A system comprised of these building blocks could be optimally designed for each operating environment or user application (see Fig. 2).

FIGURE 2

Building block approach to maximising commonality of multiple radio interfaces



The transmission dependent portion of a radio interface may be specified by combining choices made within each building block.

A set of core elements can be defined as common to all radio interfaces. This set may or may not define a complete radio interface with respect to some set of applications.

To define the concept of commonality and the procedures to maximise commonality the following model is helpful:

– specify a set of applications by identifying all possible combinations of services and operating environments. This set of applications shall, by its specification, be a complete list of all features offered to the IMT-2000 user;

– define a generic set of building blocks that constitute a radio interface;

– use these sets as axes in a matrix demonstrating the two approaches. The matrixes are shown in § 7.4.

7.4 Approaches to achieve commonality

Figures 3 and 4 conceptualise how the core elements of the radio interface can be used to maximise commonality. The process of defining the IMT-2000 interface(s) contains two steps:

– defining core elements. The core elements may or may not define a complete radio interface with respect to some set of applications;

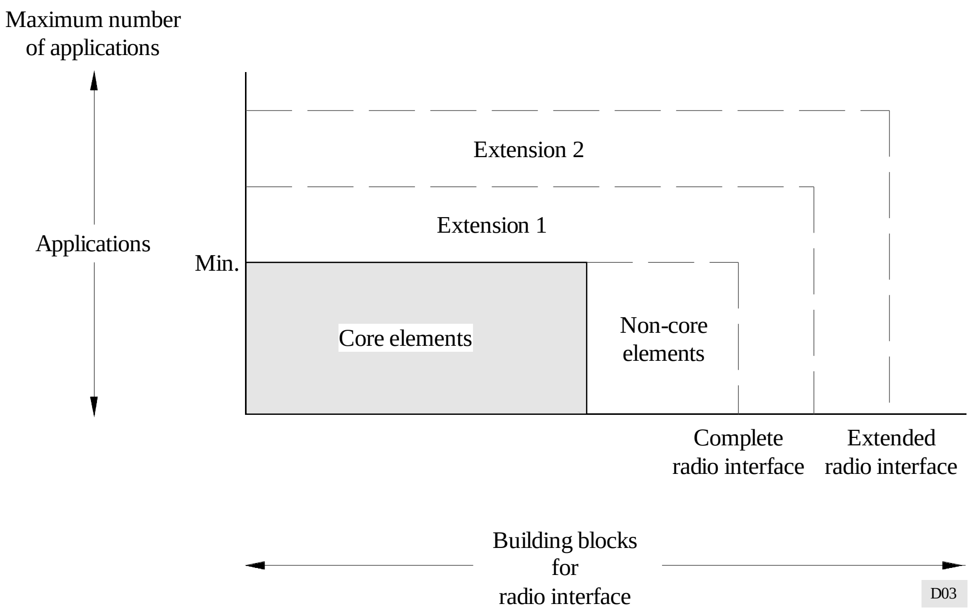
– finding extensions to the core elements to support all applications.

Methods to achieve this can be:

Method I – Focusing the efforts to a best suited set of core elements that may not define a complete radio interface but with a number of suitable extensions gives a cost/complexity optimised solution for the entire set of applications. To specify a complete radio interface for a minimum set of applications, a number of non-core elements may need to be added to the core elements.

FIGURE 3

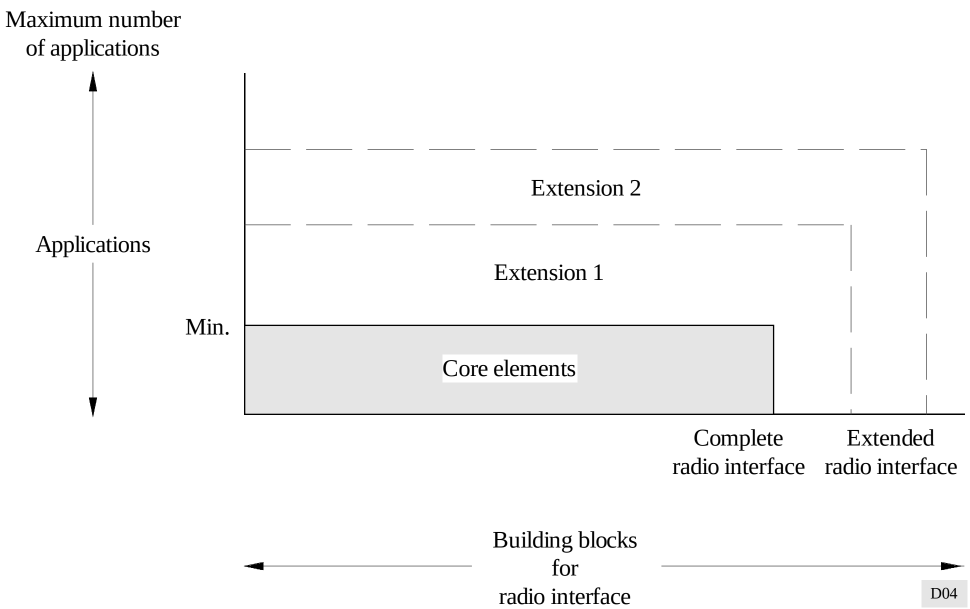
Radio interface Method I



Method II – This is a special case of the first method in which the core elements define a complete radio interface. Efforts are focused towards finding a complete radio interface containing core elements with sufficient flexibility and quality to support as many applications as possible. In this case, a set of most common applications is defined and the core elements needed to support them in one complete radio interface are identified. Extensions to the complete radio interface are added to support additional applications.

FIGURE 4

Radio interface Method II

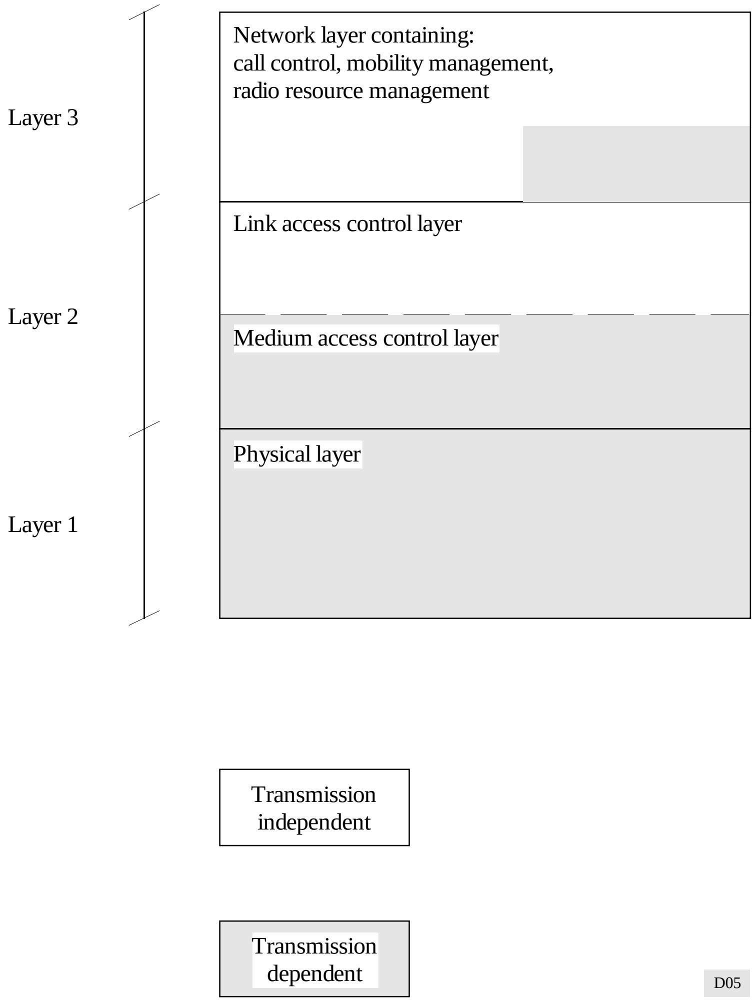


8. Protocol outline

Protocol layering will be adopted for structuring the radio interface functions. The presently envisaged basic radio protocol model is outlined in Fig. 5. It includes both a formal protocol layering and a layering referring to whether the functions are radio transmission dependent or not.

FIGURE 5

Presently envisaged protocol model



In the formal layering, layer 1 is the physical layer. The traditional layer 2, the data link layer, comprises two sub-layers: Medium Access Control (MAC), and Link Access Control (LAC). Layer 3 contains functions such as call control, mobility management and radio resource management some of which are transmission dependent. Furthermore, for many types of user services layer 3 will be transparent for user data.

Additionally, there may be a need for a system management entity performing various system maintenance and network tasks, which does not fit into the traditional protocol stack.

There may be important physical dependencies between the physical layer and the medium access control layer and possibly also with the link access control layer. It is desirable to maintain layer 3 as far as possible radio transmission independent.

8.1 Physical layer

The physical layer provides a radio link over the radio interface(s), characterised by its throughput and data quality.

It is desirable that transmission quality requirements from the upper layers to the physical layers be common for all services.

8.2 Medium access control layer

The medium access control layer controls the physical layer radio link and performs link quality control and mapping of data flow onto this radio link.

It is intended that commonalities in the medium access control layer of the various radio interfaces should be identified and exploited where possible.

8.3 Link access control layer

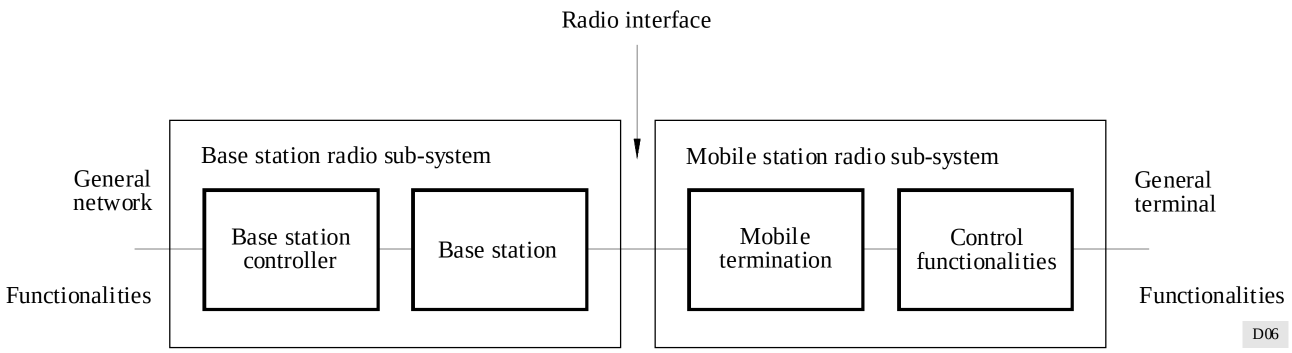
The link access control layer performs the functions essential to set up, maintain and release a logical link connection. A common protocol system for link access control, which supports a range of control modes, may be applied to all radio interfaces. The link access control layer may be common for all radio interfaces. It should as far as possible not contain radio transmission dependent functions.

8.4 Functional groups

The IMT-2000 network architecture is defined in Recommendation ITU-R M.817. A high level functional model as seen by the IMT-2000 radio sub-system is given in Fig. 6. It should be noted that there may be many ways of mapping the detailed functionalities of Recommendation ITU-R M.817 onto this model. The high level functional model in this Recommendation is not meant to imply any physical implementations.

FIGURE 6

A high level radio sub-system functional model and functional groups



In this high level model, control functionality is separated from radio relay functionality in both the base station and mobile station radio subsystem. Radio relay functionality includes functions up to layer 3 only. Control functionality includes functions down to the link access control layer only. This is depicted in Fig. 7.

9. Channel structure

9.1 Radio-frequency channel (RF channel)

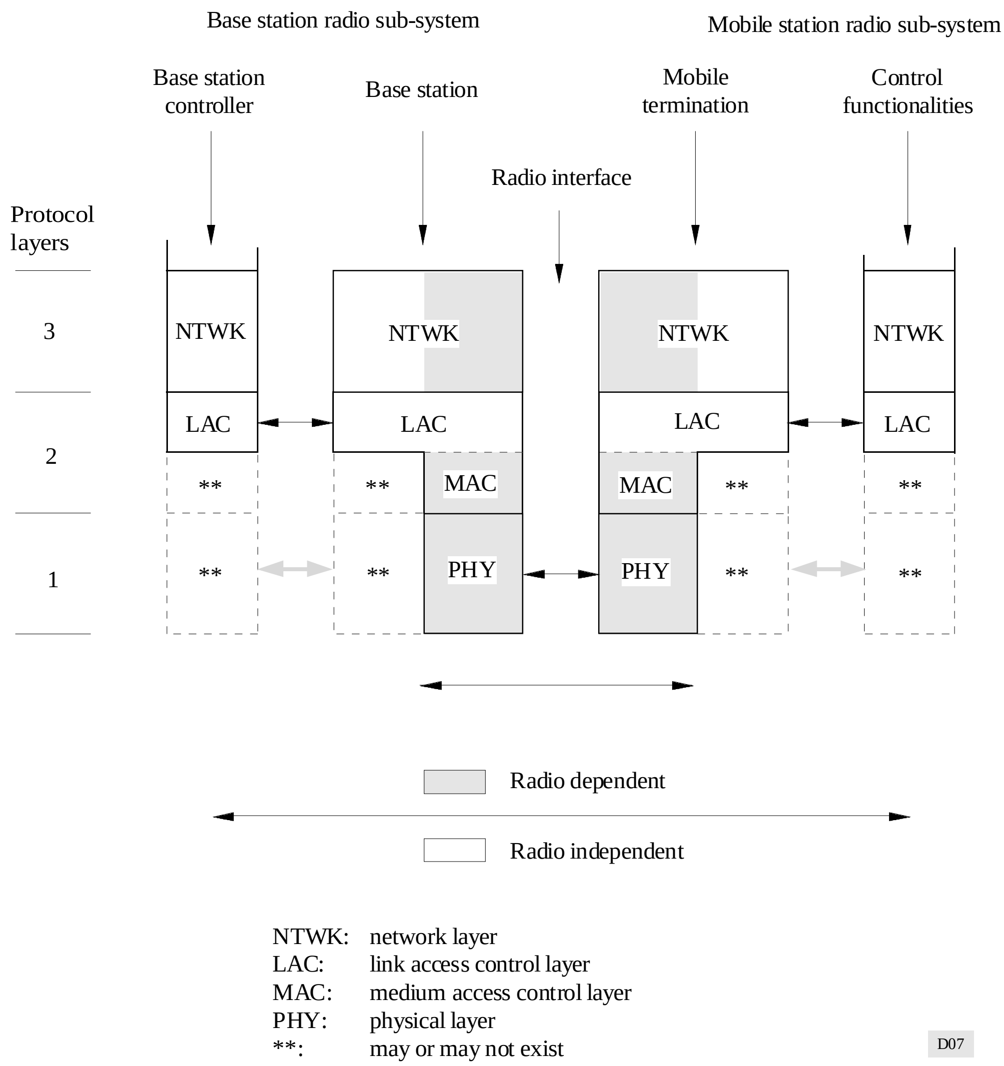
A radio-frequency (RF) channel represents a specified portion of the RF spectrum with a defined bandwidth and a carrier frequency and is capable of carrying information over the radio interface(s).

9.2 Physical channels

The physical channel is a specified portion of one or more radio-frequency channels as defined in frequency, time and code domain. Depending on spectrum availability, service requirements etc., the physical channel structure may change in time. There will be both circuit and packet switched channels.

FIGURE 7

Radio sub-system protocol model



9.3 Logical channels

Figure 8 shows the logical channel structure for IMT-2000. Certain services and functionalities may use a subset of this structure. The subset may change in time.

Logical channels are mapped onto one or more physical channels. There are two main categories of logical channels:

– control channels, which primarily carry system management messages,

– traffic channels, which carry user's speech or data.

9.3.1 Control channels

Control channels are primarily intended to carry signalling information for call management, mobility management and radio resource management.

A mobile station channel configuration contains one or more control channels. These control channels may change in time, with the channel configuration.

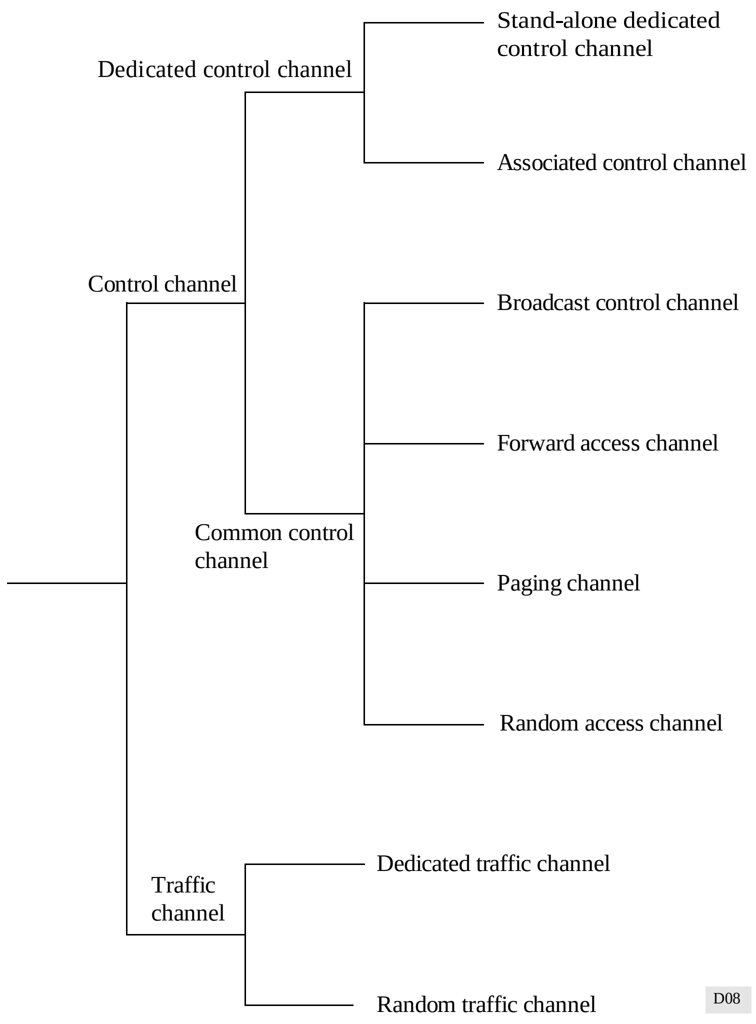
Control channels are further divided into different control channel types, which have common characteristics:

– common control channel,

– dedicated control channel.

FIGURE 8

Logical channel structure



9.3.1.1 Common control channels

A common control channel (CCCH) is a point-to-multi-point control channel that carries connection-less messages, primarily intended to carry signalling information necessary for access management functions. The types of messages that might be expected on the common control channel are:

– broadcast information,

– access request,

– access grant,

– paging messages,

– user packet data.

Four different types of common control channels are to be found; broadcast control channels, random access channels, forward access channels and paging channels.

– *Broadcast control channel*

A broadcast control channel (BCCH) is a point-to-multi-point unidirectional control channel, from the IMT-2000 infrastructure to the mobile stations. A BCCH is intended to broadcast a variety of information to the mobile stations. All mobile stations shall listen for the BCCH before making an access attempt.

– *Random access channel*

The random access channel (RACH) is a uni-directional control channel in the reverse link. An RACH carries a number of messages, such as call establishment requests and responses to network originated enquiries.

– *Forward access channel*

The forward access channel (FACH) is a uni-directional control channel from the network side to the mobile stations. A FACH carries a number of system management messages such as enquiries to the mobile station and radio- and mobility related resource assignments. A FACH may also carry packet-type user data.

– *Paging channel*

The paging channel (PCH) is for paging the mobile stations, which is the act of seeking a mobile station when an incoming call has been placed to it.

9.3.1.2 Dedicated control channels

A dedicated control channel (DCCH) is a point-to-point bi-directional control channel. There may be DCCHs with a variety of bit rates. DCCHs are further classified according to technical characteristics:

– *Stand alone dedicated control channel*

A stand alone dedicated control channel (SDCCH) is a DCCH whose allocation is not linked to the allocation of a traffic channel (TCH).

– *Associated control channel*

An associated control channel is always allocated together with a TCH or a SDCCH.

9.3.2 Traffic channels

Traffic channels are intended to carry a wide variety of user information streams. Traffic channels may be used to provide access to a variety of communication modes within the IMT-2000 and the networks to which IMT-2000 permits access. There are two types of traffic channels classified according to technical characteristics:

– *Dedicated traffic channel*

A dedicated traffic channel (DTCH) is a bi-directional or a uni-directional channel in the forward link carrying user information.

– *Random traffic channel*

The random traffic channel (RTCH) is a uni-directional traffic channel in the reverse link. An RTCH carries packet-type user data.

To facilitate interworking with ISDN, traffic channels should offer a functionally equivalent capability to the ISDN B channels. The exact data rate or the range of data rates supported will be radio transmission specific. Constraints imposed by radio transmission, spectrum availability, and economics may make it difficult to provide full ISDN B channel capability.

9.4 Frame structure

A frame structure may be applied as a way of partitioning a physical channel, where each frame may be assigned for a different purpose in communication management (e.g. one frame for BCCH and another for PCH). A fixed or variable frame structure may be envisaged.

9.5 Multiplexing

Multiplexing is the process where the logical channels are combined. Multiplexing may be achieved using a framed structure.

In the interest of maximising commonality across the IMT-2000 radio interfaces, there could be advantages in separating the multiplexing function into transmission dependent and transmission independent components. The latter component should be maximised.

The multiplexing scheme should take into account the performance requirements of the various services and use this information to dynamically optimise the information flow over the assigned radio resource.

10. Cellular aspects

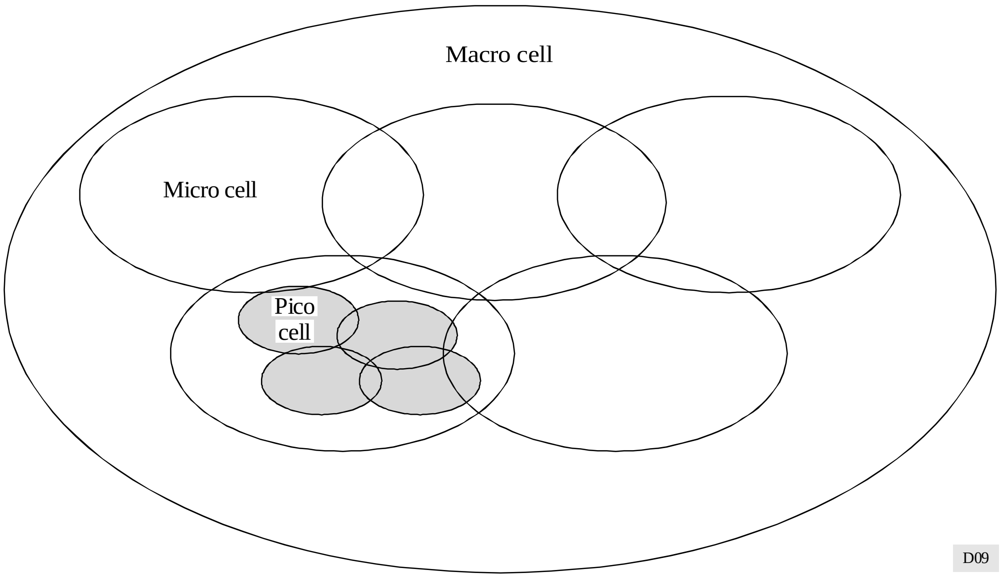
This section deals with the definition of the cellular environment that IMT-2000 is operating in. This includes the definitions of a layered cell structure and the use of cell coverage extensions.

10.1 Cell description

In order to establish high traffic capacity in IMT-2000 systems with minimal handovers for mobile stations at various speeds, in addition to maximising spectral efficiency, it may be beneficial for the cells of IMT-2000 to have different cell types related to mobile station parameters, such as mobility characteristics, output power and types of services utilised. A cell layer would contain cells of the same type in an IMT-2000 service area. In principle, it is possible to operate these different cell types simultaneously in the same geographical area, as depicted in Fig. 9. All cells in the cell layer are fully or partly sharing the same spectrum resource (e.g. sub-bands).

FIGURE 9

Multi-layered cells



This layering of cells does not imply that all mobile stations have to be able to connect to all base stations that cover the spot where the mobile station is situated (e.g. due to output power or service restriction).

The cell layers can be put into four categories; mega (satellite) cells, macro cells, micro cells, pico cells. However, this does not imply that there will only be these four cell layers.

The cell types used for different IMT-2000 services are up to each IMT-2000 operator. However, the size of the cells is related to radio range, and thus puts some requirements on the design of the radio interface(s). Some typical cell parameters for these cell types are shown in Table 1.

TABLE 1

Example of typical cell type parameters

Cell type	Mega cell	Macro cell	Micro cell	Pico cell
Cell radius	100-500 km	≤ 35 km	≤ 1 km	≤ 50 m
Installation	LEO/HEO/GSO	top of building/ tower, etc.	lamp-post/ building wall	inside building
Terminal speed		≤ 500 km/h	≤ 100 km/h	≤ 10 km/h

10.1.1 Mega (satellite) cells

Mega cells provide coverage to large areas and are particularly useful for remote areas with low traffic density. Due to their size, mega cells will provide coverage in many kinds of environment, from remote to urban, even in areas without access to terrestrial telecommunications networks and in developing countries this may be the only cell type available, even in urban areas.

Currently, mega cells can only be practically provided by satellite and the term *satellite cell* is sometimes used interchangeably with *mega cell*. However, it may be possible in the future for satellites to provide macro cell coverage also. Hence the term *mega cell* is used.

The cell size will generally be very large and dependent upon satellite altitude, power and antenna aperture; and leads to long distances between the mobile station and base station. Furthermore, the mega cell is characterised by low traffic density in comparison with terrestrial cells and the mega cells can support very high mobile station speeds. Unlike the terrestrial IMT-2000 cell types which can usually be optimised for type of environment (building and foliage blockage) and mobile station speed, the mega cell must be both flexible and robust to accommodate the broader range of its user scenarios.

It should be noted that for non-geostationary orbits, the satellite generated cells will be moving with respect to the Earth since the satellite is rotating around the Earth. This may force a handover in some cases even though the mobile station may be stationary.

10.1.2 Macro cells

The macro cells are outdoor cells with a large cell radius, typically up to 35 km. However, this can be extended by for example, the use of directional antennas.

Macro cells are characterised by low to medium traffic density, support for moderate mobile station speeds and narrowband services. A typical macro cell may be situated in a rural or suburban environment, with moderate building blockage, and, depending on terrain, significant foliage blockage.

10.1.3 Micro cells

The micro cells are outdoor cells with low antenna sites, predominantly in urban areas, with a typical cell radius of up to 1 km.

Micro cells are characterised by medium to high traffic density, low mobile station speeds and narrowband services. Blockage by man-made structures may be significant in a micro cell environment.

10.1.4 Pico cells

The pico cells are very small cells with a typical cell radius of less than 50 m. These cells are predominately situated indoors and are to give a very high traffic capacity.

Pico cells are characterised by medium to high traffic density, support for low mobile stations speeds and wideband services.

10.2 Cell coverage extension

The use of repeaters in rural areas may be required to extend the coverage of a base station to provide access to users who are either too far away or obstructed by terrain. To function over large distances (from a base station) and to cope with terrain obstruction, it may in some cases be useful to connect a number of repeaters in tandem, perhaps in the order of 10 in some cases. (This will lead to cell shapes that fall outside the scenarios outlined above.)

The electronic circuitry in the repeater will add time delay in the transmission path as well as propagation delay due to the distance between the base station and the ultimate user station. Without unduly constraining IMT-2000 design, the timing frame structure and related software should take into consideration the need to accommodate these time delays from the outset so that repeaters may be used as and when required.

10.3 Multi-layered cell features

10.3.1 Multi-operator considerations

Multiple operators may coexist in the same geographical area in an uncoordinated manner.

IMT-2000 has also to consider operation in the unregulated environment, i.e. usually private extensions of the fixed telecommunications network in private residences or office, where a large number of uncoordinated operators have to share the same frequency band.

10.3.2 Handover

Handover between cell layers should be possible for mobile stations that are intended to utilise different cell types. Additional discussion of handover is contained in § 11.

10.3.3 Cell layer selection

When a mobile station is to either initiate or receive a call (or send or receive data), a decision must be made as what type of cell shall be accessed, speed relative to serving base station, cell availability, and required transmission power to/from the mobile station should be the criteria for cell selection. When several cell types are available, the cell that is most cost and capacity efficient should be chosen, which is usually the cell that requires the least power to communicate to/from the mobile station.

11. Link control and system management functions

The system management functions include all functions needed to establish, maintain and release a connection between a mobile station and a base station. These functions could be structured in an hierarchical way:

– link quality measurements,

– cell selection,

– channel management strategies,

– channel selection/assignment,

– handover,

– mobility supporting functions (such as logon and logoff, and location updating).

11.1 Radio link quality measurements

The radio link quality of the forward and reverse links should be measured continually. This should be achieved by monitoring, as a minimum, the received signal quality. Optionally, additional methods to determine link quality may be used, such as monitoring bit error rates.

11.2 Cell selection

Cell selection may be based on several criteria. These criteria will depend on the particular service being provided to the end-user. Some services may require the ability to interwork between different cell layers. To assist the network in providing these services, appropriate information (e.g. relative speed of the mobile) could be communicated to the network.

Two different cell selection procedures could be foreseen, initial cell selection (locking) and cell re-selection.

11.2.1 Initial cell selection

When a mobile station is just switched on, it has no information regarding potential operators and their covering cells. The mobile station first searches available frequency bands for appropriate operators. The selection of the operator is based on the following:

– user preferences,
– available networks,
– mobile station capabilities,
– network capabilities,
– mobile station mobility,
– service requirements.

When a system has been selected, the mobile station will search for the appropriate base stations and lock to it. The criteria for locking to a base station and thus listening to its broadcast control channel includes:

– it belongs to the selected operator,
– it is rated "best" according to signal quality,
– the mobile station is authorised to access it.

When the mobile station has locked to the base station, it enters the idle locked mode. If no suitable base station is found within a certain time frame, the mobile station instead returns to the idle unlocked state.

11.2.2 Cell re-selection

In active mode, the mobile station periodically (or continually) measures the signal quality, monitors the cell information on the broadcast channel and updates its cell profile list of surrounding cells whilst stationary or on the move. This monitoring forms the basis for the cell re-selection procedure (however, this does not imply where this procedure is located).

The cell re-selection may be triggered by one of the following circumstances:

– the current cell is no longer suitable, due to interference situation or output power requirements,
– radio link failure,
– network request,
– traffic load considerations,
– user request.

11.3 Channel selection/assignment

Channel selection/assignment is the process by which the system ascertains the available channels and then assigns one or more of these channels to a call by means of a channel assignment algorithm. The algorithm may consider:

- system load,
- traffic patterns,
- service types,
- service priorities,
- interference situation.

11.4 Channel access and release

The channel access is the process by which a connection is established on the physical channel(s). The probability of success is dependent on the interference situation and the cell geometry.

The channel release is the process by which a connection is terminated by the release of the physical channel(s) involved.

11.5 Handover

Handover is the change of the physical channel(s) involved in a call whilst maintaining the call. The changed channels may include wireline network paths as well as radio channels. In support of terminal mobility, handover is necessary to prevent the call to a mobile terminal being released when crossing cell boundaries or when experiencing degraded radio conditions.

11.5.1 Types of handover

The types of handover applicable to IMT-2000 include:

- intra-cell handover (within one cell),
- inter-cell handover (between cells in same cell layer),
- inter-layer handover,
- inter-network handover.

11.5.2 Handover strategies

Examples of handover strategies applicable for IMT-2000 are:

- mobile controlled handover, in which the mobile station controls the evaluation phase prior to handover initiation, as well as the handover execution;
- mobile assisted handover, in which the base station controls the handover process, with support (e.g. in terms of measurements) from the mobile station;
- base controlled handover, in which the base station controls the evaluation phase prior to execution, as well as the handover execution.

11.5.3 Handover process

From a transmission point of view, the handover process may be separated into two main phases:

- the handover evaluation phase,
- the handover execution phase.

11.5.3.1 Handover evaluation

During the evaluation phase, the mobile station and/or base station continually evaluate whether there is any reason to carry out a handover. This process includes scanning of the IMT-2000 frequency band for appropriate operators, operating environments etc., and gathering of the relevant data, so that the need for handover may be evaluated. Handover may be initiated for a number of reasons.

Network initiated handovers:

– operation and maintenance,

– radio channel capacity optimisation.

Transmission initiated handovers:

– poor radio transmission conditions (delay spread, etc.),

– signal level variability,

– significant amount of interference.

Transmission initiated handover criteria for IMT-2000 may include:

– signal strength (measurements),

– signal-to-interference ratio (possibly in terms of bit-error rate or other appropriate quality of service parameters),

– distance from base station to mobile station,

– mobile station speed,

– mobile station mobility trends.

These criteria may involve data concerning the current channel, other available channels, other cells or base stations in the same radio operating environment and cells or base stations supporting other appropriate radio operating environments, etc. These transmission initiated handover criteria must be appropriately averaged, and must also be assessed so that stability in the handover mechanisms are ensured (e.g. with appropriate hysteresis margins). Further, the data may be gathered independently in the forward and the reverse link , depending on the handover strategies used.

11.5.3.2 Handover execution

If the handover evaluation concludes that handover is desirable, the decision to execute handover is made, and handover procedure is subsequently commenced. The handover decision is made by the mobile station or the base station, depending on the handover strategies used.

The exact algorithm for making handover decisions may possibly not be an issue for standardisation. This may, however, depend on the overall handover strategies used, which again may depend on the operating environment.

11.6 Functions supporting mobility

In order to support mobility between clusters of cells and between systems, there is a need for certain functions in the mobile station and the fixed network.

11.6.1 Logon and logoff

Logon and logoff messages are transmitted from the mobile station to the network in order to notify the network of a terminals status. This does not exclude the possibility of the network initiating such procedures.

11.6.2 Location updating

The purpose of location update is to identify the area in which a mobile station is located. The location area is that geographical area in which the network will search for the mobile station. A location update is performed when a mobile station enters a new location area. There is a trade-off between the frequency of location updating and the size of the location area.

12. System performance issues

12.1 Interference control

Synchronisation, power control and radio resource management are all factors which need to be considered with regard to interference control. In a scenario where multiple systems may co-exist it is of particular importance to ensure that intra-system and inter-system interference is kept to acceptable levels.

12.1.1 Synchronisation

The implications of synchronisation that should be considered when evaluating different transmission technologies are:

– time synchronisation between base stations within the same system,

– time synchronisation between base stations in different but geographically co-located systems,

– time synchronisation between subscriber terminals and base stations,

– impact of signalling,

– synchronisation requirements,

– accuracy of synchronisation.

12.1.2 Power control

Power control is utilised in order to minimise both intra- and inter-system interference. Output power from both the mobile and the base stations may be controlled with an open or a closed loop power control scheme.

12.1.3 Radio resource management strategies

In any type of radio resource management the total radio resources available are divided according to traffic demand between different cell layers and operators. However, in order to minimise the overall interference within the frequency band while maximising the traffic carried, the resource allocation strategies may need to be based on a dynamic approach.

In the long term, IMT-2000 networks may need the ability to re-configure their use of assigned frequency blocks in response to changing traffic, service requirements or spectrum allocations. This ability will also be required in the office and residential environments.

12.2 Diversity strategies

Diversity techniques may provide for increased system capacity and improved quality service and should therefore be considered when implementing IMT-2000. Diversity may be achieved in several ways for either transmission or reception, which include the following:

– antenna space diversity,

– base station space diversity (macro diversity),

– path diversity,

– frequency domain diversity,

– time domain diversity.

Diversity may put requirements on the specification of the radio interface(s) and the radio sub-system and thus need to be considered in the specification of the link control and system management functions. The impact on the fixed network infrastructure should also be considered.

12.3 Variable data rate control

Several approaches may be used to ensure that perceived demands for variable data rates are met:

– direct support of variable data rates over the air interface(s),
– change the number of bearer channels so that a multiple of bearer channels are combined to handle the desired user rate,
– packet access.

12.4 Capacity improvements techniques

The IMT-2000 radio interface(s) should facilitate the implementation and use of appropriate capacity improvement techniques. However, the applicability of these is dependent on the multiple access scheme chosen. Examples of capacity improvement techniques applicable for IMT-2000 are:

– slow frequency hopping,
– dynamic power control,
– dynamic channel allocation,
– discontinuous transmission for voice, including voice activity detection, and non-voice services,
– source codecs with lower and variable average bit rates.

12.5 Battery saving techniques

The IMT-2000 radio interface(s) should facilitate the implementation and use of battery saving techniques. Examples of such techniques are:

– output power control,
– discontinuous reception,
– discontinuous transmission.