REPORT 1153

# FUTURE PUBLIC LAND MOBILE TELECOMMUNICATION SYSTEMS

(Question 39/8)

(1990)

## 1. Introduction and summary

Interim Working Party 8/13 was set up by Decision 69 in 1985 with the task of investigating the form of Future Public Land Mobile Telecommunication Systems (FPLMTS) with particular regard to the overall objectives, suitable frequency bands and the degrees of compatibility or commonality and which has resulted in the preparation of a new Recommendation 687 on FPLMTS.

This Report summarizes the result of the study.

From the beginning of the study it was apparent that a light-weight personal pocket radio would be a dominant feature of FPLMTS. Most administrations advocated the desirability of such a personal station (PS) being usable anywhere world-wide, with the inherent implication of a requirement for a single radio interface standard. However, considerations of the varieties of radio coverage scenarios for personal communications (from very short range ones for use within buildings or urban areas through medium range suburban and longer range rural coverage, together with the desire for links to aircraft or satellites) indicated that a number of RF transmission requirements and frequency bands are likely to be required. Moreover, a tandem link could well be involved from the PS via another mobile connection. There is a possibility that the final link to the PS could be the same. However, the situation of the vehicle mounted mobile accessing terrestrial links is different, and some administrations emphasized the much reduced requirements for inter-regional roaming (although international roaming within a region will be a requirement). Hence, it was agreed that greater flexibility for regional standards for roaming is needed. Nevertheless, it was also recognized that a common world-wide radio interface and frequency band may increase the possibility of reduced costs of network and terminals and availability of equipment.

The frequency allocations made by WARC-MOB-87 for the land mobile satellite service also influenced the study on FPLMTS, with the realization of the opportunities that satellite links could bring to such systems.

A number of objectives for FPLMTS has been agreed. It was found desirable to partition them into 19 primary ones and 10 secondary. The secondary status allows more freedom of choice for implementation.

The FPLMTS could be considered as either an adjunct to or an integral part of the fixed network (PSTN/ISDN). The particular characteristics of the radio channel will, however, impose some constraints on the services offered as well as providing opportunities for others such as dispatch, group call, etc. Service should be provided to a variety of mobile terminals ranging from the PS to vehicle mounted mobile stations (MS). Additionally FPLMTS should be usable as a temporary or permanent substitute for the fixed network. The standards of services provided should be comparable with those of the fixed network, and particular attention will have to be paid to the need for enhanced privacy/security on the radio channel (not only for speech, but also for billing, etc.).

Two complementary scenarios are postulated. The first is concerned with land-based systems. This involves the PS operating in five modes, i.e. accessing a private "domestic" base, accessing a private office base, accessing a public personal base, accessing a public mobile base directly or communicating via an MS. The MS is linked to a base station (BS) for its mobile service and operates either in its own right or as a relay for a PS. The second scenario involves satellite links to mobile earth stations (MES) either in their own right or for relay to a PS. Also envisaged are satellite and terrestrial paging systems.

An architecture is defined that shows interfaces within the FPLMTS and with the fixed network. The functionality of the mobile equipment is also indicated.

The factors which affect the choice of desired frequency bands of operation are discussed. Starting with services to be offered and traffic models, estimates are made of the requirements of such factors as modulation, coding, re-use, etc., in order to assess the bandwidth requirement. This Report also contains comments on the choice of frequency bands including any biological factors.

The desire for compatibility within and between FPLMTS is commented on in several sections of the present Report as are the benefits of commonality. Considerations of compatibility with the ISDN give rise to the concept of mapping its B (bearer) and D (signalling) channels onto I (information) and C (control) channels for FPLMTS.

## 2. Objectives for future public land mobile telecommunication systems

FPLMTS should aim to achieve the following objectives which are classed as primary and secondary. Secondary objectives are those which some administrations or regions may not wish to include. Within each class the numbers are for reference purposes only and do not convey an order of priority.

PRIMARY:

P1. To make available voice and non voice telecommunication services to users who are on the move or whose location may change (mobile users).

P2. To provide these services over a wide range of user densities and geographic coverage areas.

P3. To make efficient and economical use of the radio spectrum consistent with providing service at an acceptable cost.

P4. To provide, as far as practical, a service of high quality and integrity, comparable to the fixed network.

P5. To accommodate a variety of mobile terminals ranging from those which are small enough to be easily carried on the person (the personal pocket radio), to those which are mounted in a vehicle.

P6. To provide a framework for continuing extension of mobile network services, and access to services and facilities of the fixed network (PSTN/ISDN) subject to the constraints of radio transmission, spectrum matters and system economics.

P7. To admit the connection of mobile users to other mobile users or fixed users, using the fixed network (PSTN/ISDN) or other telecommunication networks as appropriate.

P8. To permit the use of the FPLMTS for the purpose of providing its services to fixed users, under conditions approved by the appropriate national or regional authority, either permanently or temporarily, either in rural or urban areas.

P9. To admit the provision of service by more than one network in any area of coverage.

P10. To allow mobile and fixed network users to use the services irrespective of location (i.e. national and international roaming).

P11. To provide for the required user authentication and billing functions.

P12. To provide for unique user identification and PSTN/ISDN numbers in accordance with appropriate CCITT Recommendations.

P13. To support integrated communication and signalling.

P14. To establish signalling interface standards in terms of the Open System Interconnection (OSI) model.

P15. To provide an open architecture which will permit the easy introduction of technology advancements, as well as different applications.

P16. To enable each mobile user to request particular services, and initiate and receive calls, as desired.

P17. To allow the co-existence with, and interconnection with, mobile systems which use direct satellite links taking into consideration CCITT Recommendation E.171.

P18. To provide for a unique equipment identification scheme.

P19. To provide a modular structure which will allow the system to start from as small and simple configuration as possible and grow as needed, both in size and complexity within practical limits.

SECONDARY:

S1. To provide for additional levels of security (for voice and data services) compared to that contained in P4. In addition, to allow for the provision of end-to-end encryption for voice and data services.

S2. To provide service flexibility which permits the optional integration of services such as mobile telephone, dispatch, paging and data communication, or any combination thereof.

S3. To provide an indication to the paying party of added call charges, e.g. due to roaming.

S4. To support terminal interfaces which allow the alternative use of terminal equipment in the fixed ISDN network.

S5. To support equipment and component design that can withstand typical rural conditions (rough roads, dusty environment, extreme temperatures and humidity, etc.).

S6. To allow the system to be configured for special conditions where mobility between cells, or even within a cell, is not required~~; or where a high traffic~~ per user is required.

S7. To take account of the communications requirements for road traffic management and control systems.

S8. To accommodate the use of repeaters for covering long distances between terminals and base stations, providing this does not constrain the specification of the radio interfaces.

S9. To allow the connection of PABX's, or small rural exchanges to mobile stations.

S10. To allow for an extension of the cell size in rural or remote areas, providing this does not constrain the specification of the radio interfaces.

## 3. Services

### 3.1 *Introduction*

The concept of a service conferring mobility is one which is desired by users whether they are served by the mobile network or the fixed one. Thus it is part of future (fixed) telecommunications systems and FPLMTS. The degree of mobility is different between the networks:

Mobile Network Mobility
Mobility involves the ability of the user to be in continuous motion (including the stationary condition) whilst accessing and using telecommunication services. This requires the telecommunication services to be available throughout a spatial volume and ideally at all times.

Fixed Network Mobility
Mobility is conferred by flexibility of access to telecommunication service provision, which is available at discrete locations, in such a way that the user identifies with, and may configure, any one of these fixed terminals to meet his requirements. These requirements may then be relocated from terminal to terminal without restriction or extent.

FPLMTS will give continuous mobility within a coverage area whilst the fixed network will give discrete mobility.

FPLMTS can also benefit from this flexibility of access concept. These "higher layers" of service are offered by FPLMTS (mobility, flexibility of access) in addition to the conventional telecommunication services.

Services which previously could be considered as specific to separate mobile (radio) systems, such as dispatch services, could now be included in the supplementary telecommunication services of FPLMTS.

Services will be described under seven main headings: General Requirements, Mobility, Service Access, Telecommunication Services, Basic Speech Quality, Security, Quality of Service.

Note: The CCIR considers that the differences from a user perspective between the services provided by the mobile and fixed networks will become less into the future. It will become increasingly difficult for users to differentiate between these two networks.

### 3.2 *General requirements*

FPLMTS may be either an adjunct to or an integral part of the PSTN/ISDN. The services offered in the PSTN/ISDN and other public networks should as far as possible be available in FPLMTS bearing in mind the differences in the characteristics of the fixed network and mobile radio environment. FPLMTS may also offer additional services, taking into account the special nature of mobile communications.

FPLMTS should be designed to allow international operation and automatic roaming of mobile subscribers and stations. The degree to which the roaming facility between networks (or countries) shall be automatic is not yet decided. There will also be a need for FPLMTS to have the capability to restrict roaming and access to and from unauthorized mobile subscribers or stations.

FPLMTS should be designed in such a way that the location of a roaming user should not be disclosed to a calling user without the agreement of the called party. Conversely, the location of a calling user, when roaming, should not be disclosed to the called party without the calling party's agreement.

The services and facilities offered in FPLMTS may not always be the same over all the system.

The FPLMTS should be designed so that under favorable circumstances services requiring high information rates can be provided. For example if the mobile terminal is stationary, or moving slowly, and is close to a base ~~station which is not heavily loaded~~ otherwise, it may be possible to provide services up to the primary ISDN rate of 1536 or 1920 kbit/s. Under less favourable circumstances (e.g. mobile terminals at greater distances from the base station or when the base station is carrying a heavy load of traffic) the services may be restricted to those using lower rates.

It should be possible for terminal stations in FPLMTS to be used in the maritime and aeronautical environment, to the extent permitted by national or international regulatory authorities.

FPLMTS should be capable of providing service to a variety of mobile terminals ranging from those which are small enough to be easily carried on the person to those which are based in a vehicle [De Brito, 1981].

It should be possible for FPLMTS to be used as a temporary or permanent substitute to fixed networks where fixed network facilities are limited or not available, or more generally where reasons of convenience or economics make this desirable. The system should then be capable of adaptation to these conditions (i.e. higher traffic per user, no movement between cells or even within a cell).

## 3.3 *Continuous mobility*

### 3.3.1 *Definition*

Continuous mobility is the ability to access and use telecommunication services whilst in continuous motion (including whilst stationary), by the provision of telecommunication facilities which are available everywhere within a spatial volume and ideally at all times.

### 3.3.2 *Constraints.*

Within this definition the degree of continuous mobility may be constrained. In general the constraints will depend on the type of terminal used to access the service. The following identifies the constraints on the mobility of the terminals in order to have the FPLMTS services available.

(i) The personal station PS (e.g. pocket-sized portable) can be used in various ways with identifiable constraints. Within buildings the rate of motion will be limited to walking speed. A similar speed constraint applies when the PS is used in a moving vehicle. In this case, the vehicle can provide a tandem link to the network via an MS or MES located in the vehicle. When the PS is used directly outdoors, consideration needs to be given to its use for rates of motion up to that of slow-moving vehicles in urban and suburban areas.

(ii) The mobile station MS (e.g. vehicle mounted): within defined coverage areas (e.g. urban, suburban, rural) for rates of motion of say high speed trains.

(iii) The mobile (satellite) earth station MES: within defined coverage areas (e.g. rural and remote areas, with restricted availability in urban and suburban areas) for rates of motion up to say supersonic aircraft speeds.

Notes: (1) Some administrations may wish to implement networks which allow the PS to have the mobility of the MS. The mobility constraints will also vary depending on the actual implementation technologies employed.

(2) It will be necessary to consider how to provide telecommunication services with aircraft over land which does not use an MES (see Report 1051).

## 3.4 *Service access*

### 3.4.1 *Introduction*

The FPLMTS can provide an additional degree of mobility and flexibility to the user when the Personal Telecommunication Number (PTN), as defined below, is used.

In most of the existing networks, telecommunication services are provided to the users using the identity of the equipment to be used. Often several users access the same equipment on a shared basis.

The implementation of the concepts presented in this section makes this sharing more formal: the various users that may access a particular equipment at a particular moment will not always "roam" together, making it necessary therefore to have a differentiated management for each one. As a result, precise definitions of all the concepts handled in this section have to be given.

### 3.4.2 *Definitions and comments*

All the following definitions need to be considered together; a number of them have been based on or derived from CCITT definitions.

The order in which these definitions are presented does not depend on the importance of them. The order was chosen to provide a progressive introduction to the various concepts being presented. Some definitions have been reproduced here for completeness and/or to avoid any possible misunderstanding of the new concepts.

Some of these concepts are illustrated in Fig. 1.

#### 3.4.2.1 *User*

a) Definition

The user is a person (or a person's logical function) or device/machine designated by the subscriber, individually or by class, as having access to the service and having such authorization, individually or by class, as may be required by the network operator or an authorized agent concerned. (see CCITT Recommendation I.112)

b) Comments and examples

As an implication of the concepts presented in this section, it has to be made clear that the term "user" may cover only a particular aspect of those using the network. To illustrate the consequences of this, the following examples of "users" are given:

- a person

- a particular aspect of the activity of a person (the differentiation could be made for billing purposes or for call forwarding purposes), corresponding to e.g. his/her private life, business activity (e.g. driver of a truck)

- a vehicle as such (e.g. for the purpose of managing a fleet of vehicles)

- the load of a vehicle (e.g. for the purpose of managing a fleet of containers).

In many cases the different users presented in the above example could share, for some period of time, the same mobile equipment and then roam in independent ways requiring therefore specific means of identification (see PTN here below).

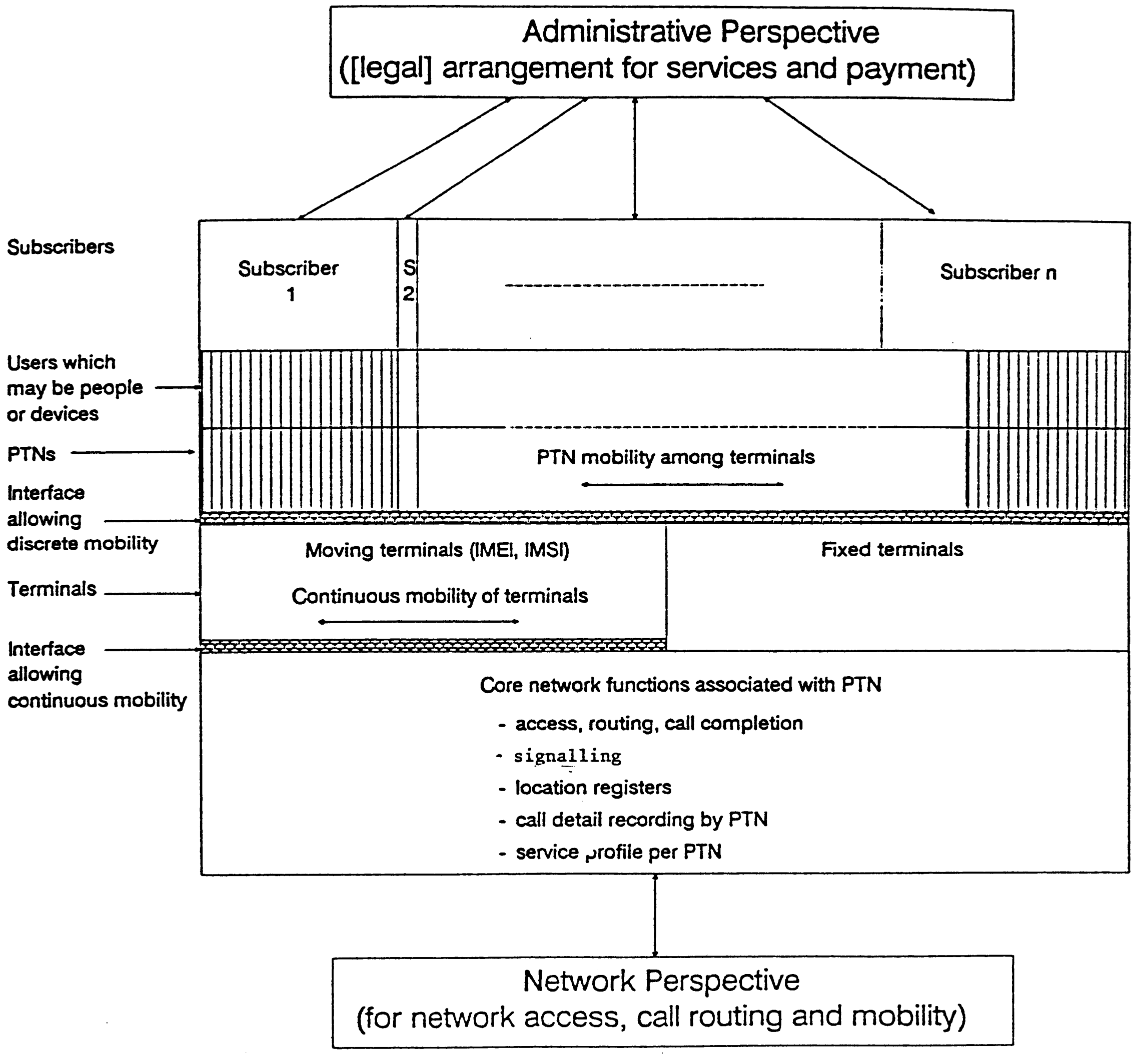



**Fig. 1 The PTN Concept**

3.4.2.2 *International mobile station equipment identity (IMEI)*

a) Definition

The IMEI uniquely identifies the mobile station as a piece or assembly of equipment.

b) Comments and/or examples

The IMEI could be a serial number of the mobile equipment, attached permanently to it.

3.4.2.3 *International mobile subscriber identity (IMSI)*

a) Definition

The IMSI uniquely identifies the mobile station as authorized by a network operator. It can be mapped directly to the existing directory number. (See CCITT Recommendation E.212)

b) Comments

In many cases, there is a one to one correspondence, at a particular moment in time, between IMEI and IMSI.

3.4.2.4 *PTN (Personal Telecommunication Number) and PTN service*

a) Definition

The PTN Service is a service supported by the FPLMTS that provides to the network the capability of identifying a particular user to be served, independently of the identity of the physical equipment (both IMEI and IMSI) serving that user.

The identifier to be used to access a particular user is referred to as the PTN of that user.

b) Comments and examples

There is a one to one correspondence between users (see definition 3.4.2.1) and PTNs.

Several PTNs may be accessed through the same terminal unit.

One PTN may be served by different terminal units for different services.

One subscriber may have several PTNs, each authorized to separate users.

By using the PTN service, users will be able to benefit from telecommunication services as independently as possible from both the physical equipment to be used and the network transporting the information. In particular, there should be no need for a calling party to know with which network the mobile is able to communicate at that particular moment.

Using the PTN, it is expected that the user can, in principle, obtain telecommunication services via telecommunication facilities belonging to any public telecommunication network (FPLMTS, PLMN, ISDN, PSTN, etc.) or associated private networks (i.e. private networks supporting the FPLMTS and PTN services).

This requires that the desired services are supported by the particular combination of network and terminal.

3.4.2.5 *Log-in*

a) Definition

In this Section 3 log-in is the action by which the user indicates to the network that all or part of the calls addressed to him (to his PTN) are to be sent to a particular telecommunication terminal equipment.

b) Comments and/or examples

In order to get service from a network with a particular physical equipment, a user can log-in using his PTN through that terminal (see 3.4.2.6).

This log-in can be done automatically when an intelligent device is connected to the terminal equipment, or manually by the user (by keying in the PTN plus some password or by the application of an intelligent/memory device).

In some cases a subscriber or his representative may also perform the log-in for a user.

The same telecommunications equipment may be shared by several users (corresponding to several PTNs). Therefore several users may simultaneously be logged in through it.

3.4.2.6 *PTN service profile*

a) Definition

The PTN service profile is the information relative to one particular PTN, that is needed in order for the network to be able to complete the call processes involved with that PTN. PTN service profiles complement any other network profiles or discriminations.

b) Comments and/or examples

There is a one to one relation between PTNs and PTN service profiles.

The services to be provided to a particular user depend upon the PTN service profile associated with his PTN.

Part of the PTN service profile will depend upon information supplied through the subscription, while another part may be updated dynamically by the user.

By using or modifying his PTN service profile, a user can also request to a network that some services addressed to his PTN be served by specified terminals (e.g. calls to be forwarded to another terminal).

In some cases a subscriber or his representative may modify the PTN service profile for a user.

The PTN service profile can also be used for selectively screening incoming calls.

3.4.2.7 *Personal Identification Number (PIN)*

a) Definition

Confidential information which may be used for the authentication of the user.

3.4.3 *Features of the PTN service*

A user can be accessed through the usage of his PTN.

The assigned PTN is independent of:

(i) physical network, including access means (e.g. radio, wire) and terminals

(ii) services (e.g. voice, data) and

(iii) geographic location.

The PTN service will provide the following:

(i) service access

(ii) location registration

(iii) pursuit routing, alerting and call delivery

(iv) authentication and

(v) charging.

The PTN is essential for automatic inter-network roaming and inter-terminal roaming.

#### 3.4.4 *Format of the PTN*

The PTN format is subject to CCITT studies. One example of PTN format can be as follows :

CC + SI + OI + PN

CC: Country code

SI: Service Indicator ( flag "PTN" or "not PTN")

OI: Operator Identity (Administration or RPOA)

PN: Personal number

### 3.5 *Telecommunication services*

#### 3.5.1 *Introduction*

The telecommunication services to be supported by the FPLMTS should reflect the needs of users to communicate in a mobile environment.

In this section the services are firstly classified from the user perspective in terms of the categories and classes of services and types of information to be communicated.

The combinations of these factors lead to specific network requirements in the form of offered teleservices and bearer capacity. The network services are subsequently defined in terms of specific attributes.

Some typical services so defined are summarized in Table I.

3.5.2 *Service categories and classes*

Three main service categories have been identified: mobility services, interactive services and distribution services as shown in Fig. 2. As indicated in this figure, these three service categories are further subdivided into nine service classes.

The mobility services are those which specifically result from the user need for mobility. The interactive and distribution services are closely aligned to those defined by CCITT for the fixed network in Recommendation I.121. The addressed one-way services have been added to the distribution service category.

**Table I**
**FPLMT Services**

| USER PERSPECTIVE | | | | FPLMTS NETWORK REQUIREMENTS | |
|---|---|---|---|---|---|
| SERVICE CATEGORIES AND CLASSES | TYPE OF INFORMATION | SERVICE DESCRIPTION | FPLMTS APPLICATION EXAMPLE | TELESERVICE | BEARER CAPABILITY |
| 1. Mobility Services | | | | | |
| 1.1. Locating | Voice | Voice announcement indicating location of user | - * | | |
| | Audio | * | - | | |
| | Text | Text information indicating location of user | - location information to dispatcher | - text | ≤ 8 kbit/s |
| | Image | Image data indicating location of user | - Mobile navigation to vehicles or dispatcher | - data | |
| | Video | * | - | | |
| | Signalling | Signalling information based on user location | - presentation of location specifics to enable user to reconfigure equipment or service profile | - data | ≤ 8 kbit/s |
| 1.2 PTN | Voice | * | | | |
| | Audio | * | | | |
| | Text | * | | | |
| | Image | * | | | |
| | Video | * | | | |
| | Signalling | Sending of users PTN or called PTN for call routing | - dialling and personal identification | - data | ≤ 8 kbit/s |
| 1.3 Dynamic Reassignment | Voice | * | | | |
| | Audio | * | | | |
| | Text | * | | | |
| | Image | * | | | |
| | Video | * | | | |
| | Signalling | Allocation of communication facility to user based on PTN profile | - facility availability signalling (available, busy, or unavailable) | - data | ≤ 8 kbit/s |

* For further study to determine potential new FPLMTS user services.

# Table I (cont.)
# FPLMT Services

| USER PERSPECTIVE | | | | FPLMTS NETWORK REQUIREMENTS | |
|---|---|---|---|---|---|
| SERVICE CATEGORIES AND CLASSES | TYPE OF INFORMATION | SERVICE DESCRIPTION | FPLMTS APPLICATION EXAMPLE | TELESERVICE | BEARER CAPABILITY |
| 2. Interactive Services | | | | | |
| 2.1 Conversational (real-time 2-way) | Voice | End-to-end 2-way voice connection | - 2-person telephone call<br>- conference telephone call | - speech | 8 - 64 kbit/s |
| | Audio | End-to-end 2-way audio connection | - audio conference<br>- interactive data using modems or DTMF tones | - programme sound<br>- data | 64 - 384 kbit/s<br>8 - 64 kbit/s |
| | | | - Control and monitoring or medical data instruments with A/D and D/A conversion | - data (telemetering and control) | 8 - 64 kbit/s |
| | Text | End-to-end data connection for 2-way presentation of text | - 2-person data call for screen sharing | - text | 8 - 64 kbit/s |
| | | | - data conference call | - text | 8 - 64 kbit/s |
| | | | - Connectionless short message conversation | - data | 8 - 64 kbit/s |
| | Image | End-to-end 2-way image connection | - 2-way fax | - telefax | 8 - 64 kbit/s |
| | Video | End-to-end 2-way video connection | - 2-way compressed video | - video phone | 64 - 1920 kbit/s |
| | Signalling | End-to-end 2-way signalling connection | - remote control and status acquisition | - signalling | connectionless packet |

Note: - There may be various combinations of services which are not symmetric in both directions but which together constitute a conversational service.
- There may also be combinations of classes of services in a given use of telecommunication services.

| SERVICE CATEGORIES AND CLASSES | TYPE OF INFORMATION | SERVICE DESCRIPTION | FPLMTS APPLICATION EXAMPLE | TELESERVICE | BEARER CAPABILITY |
|---|---|---|---|---|---|
| 2.2 Messaging (store and forward) | Voice | Store and forward voice | - voice mail box | - speech | 8 - 64 kbit/s |
| | Audio | Store and forward audio | - * | | |
| | Text | Store and forward data/text | - e-mail<br>- text paging | - text<br>- text | 100 bits/s - 64 kbit/s<br>low bit rate |
| | Image | Store and forward images | - fax mailbox | - telefax | 8 - 64 kbit/s |
| | Video | Store and forward video | - video mail | - video mail | 64 - 1920 kbit/s |
| | Signalling | Store and forward signalling | - call alerting<br>- calling number ID | - data<br>- data | 100 bits/s - 64 kbit/s<br>8 - 64 kbit/s |

* For further study to determine potential new FPLMTS user services.

**Table I (cont.)**
**FPLMT Services**

| USER PERSPECTIVE | | | | FPLMTS NETWORK REQUIREMENTS | |
|---|---|---|---|---|---|
| SERVICE CATEGORIES AND CLASSES | TYPE OF INFORMATION | SERVICE DESCRIPTION | FPLMTS APPLICATION EXAMPLE | TELESERVICE | BEARER CAPABILITY |
| 2.3 Retrieval (access to stored information) | Voice | Access to stored voice messages | - telephone access to a voice menu | - speech retrieval | 8 - 64 kbit/s |
| | | | - voice based stock quotation | - speech retrieval | 8 - 64 kbit/s |
| | Audio | Access to stored audio messages | - programme sound | - audiotex | 64 - 384 kbit/s |
| | Text | Access to stored text messages | - electronic bulletin board | - teletex | 8 - 64 kbit/s |
| | Image | Access to stored images | - real estate home listings with pictures | - telefax/image retrieval | 8 - 64 kbit/s |
| | Video | Access to stored moving pictures | - teleshopping | - video | 64 - 1920 kbit/s |
| | Signalling | Access to stored signalling | - network feature activation (call forwarding, etc.) | - data | 8 kbit/s |
| | | | - polling of telemetering station | - data | 8 - 64 kbit/s |
| 3. Distribution Services | | | | | |
| 3.1 Distribution (real-time broadcasting or narrow-casting | Voice | Voice message broadcasting or narrowcasting | - public service announcements | - speech | 8 - 64 kbits |
| | | | - taxi dispatching | - speech | 8 - 64 kbit/s |
| | Audio | Audio broadcasting | - * | | |
| | Text | Text broadcasting or narrowcasting | - * | | |
| | Image | Image broadcasting | - * | | |
| | Video | Video broadcasting | - * | | |
| | Signalling | Signalling information broadcasting | - * | | |
| 3.2 Distribution service with user presentation control | Voice | * | | | |
| | Audio | * | | | |
| | Text | Selection of one text message out of several being broad-cast simultaneously on a channel | - city information service | - text | 8 - 64 kbit/s |
| | Image | Selection of one image (etc.) | - teleshopping | - telefax/image | 8 - 64 kbit/s |
| | Video | Selection of one moving picture (etc.) | - teleshopping | - compressed video | 64 - 1920 kbit/s |
| | Signalling | * | | | |

* For further study to determine potential new FPLMTS user services.

# Table I (cont.)
# FPLMT Services

| USER PERSPECTIVE | | | | FPLMTS NETWORK REQUIREMENTS | |
|---|---|---|---|---|---|
| SERVICE CATEGORIES AND CLASSES | TYPE OF INFORMATION | SERVICE DESCRIPTION | FPLMTS APPLICATION EXAMPLE | TELESERVICE | BEARER CAPABILITY |
| 3.3 Addressed one-way (real time) | Voice | Voice message | - voice paging, individual or group call | - speech | 8 - 64 kbit/s |
| | Audio | * | | | |
| | Text | Text message | - radio paging with text display, individual or group call | - data | 8 - 64 kbit/s |
| | Image | Addressed image | - telefax, point-to-point or point-to-multipoint | - telefax | 8 - 64 kbit/s |
| | Video | * | | | |
| | Signalling | Signalling message | - radio paging, alerting only | - data | ≤ 8 kbit/s |

* For further study to determine potential new FPLMTS user services.

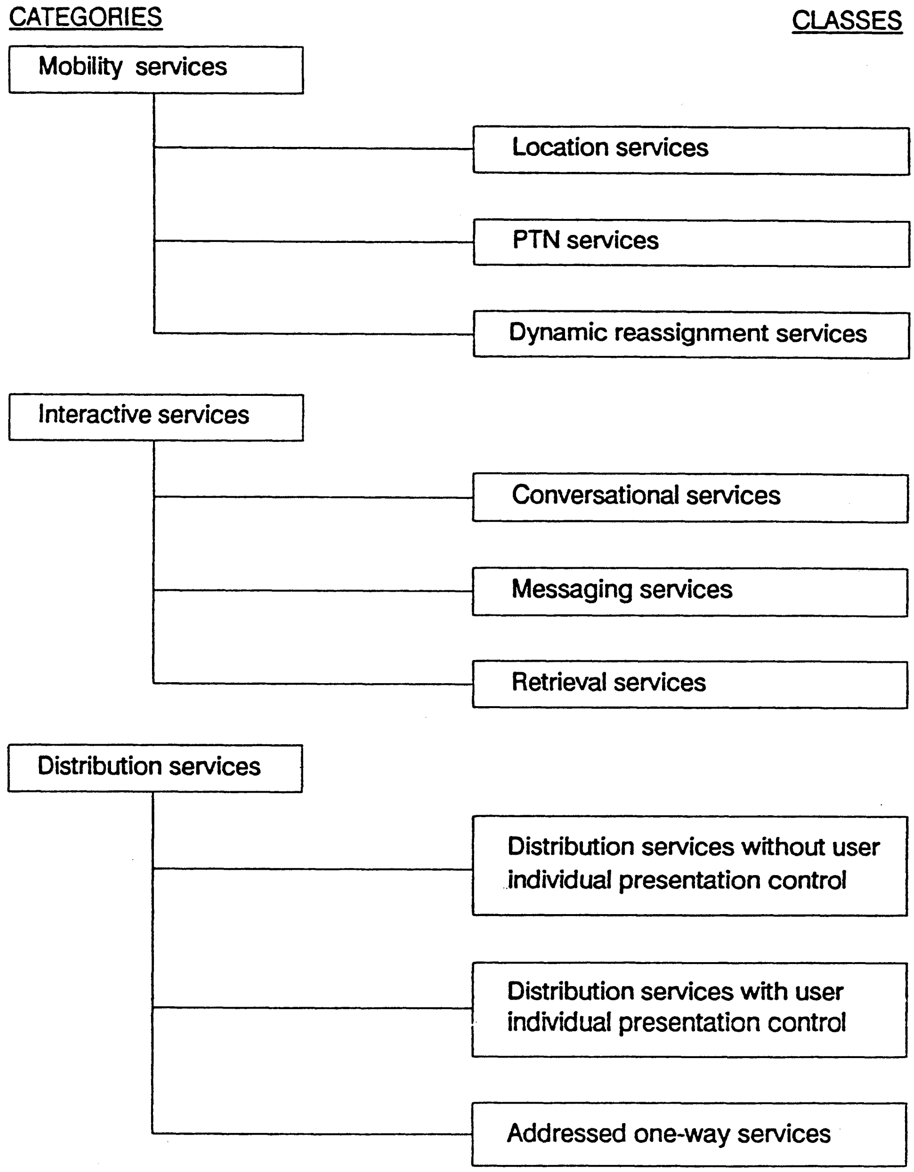



**Fig. 2**
**Classification of mobile services**

3.5.3 *Definition of the various service classes*

The definitions for the mobility services are based on the concepts of mobility introduced in 3.1 through 3.4. The definitions for the interactive distribution categories of services which follow are extracted from CCITT Recommendation I.121 and are presented here for completeness. The definition of the addressed one-way services are based on actual network services, such as radio paging with real time voice.

3.5.3.1 *Location services*

For successful operation, FPLMTS must know the location of the mobile unit to some level of accuracy. This capability is the cornerstone for world-wide personal telecommunications. Location information may be provided to authorized users by FPLMTS, e.g. to relevant authorities in cases of emergency calls or for vehicular traffic management. In order to protect the privacy of the user, the access to location information must be restricted to specific applications authorized by the customer and the administration concerned.

3.5.3.2 *PTN services*

The PTN services are defined in 3.4. They provide flexible access to either the fixed network or FPLMTS for users who require mobility as part of their communication needs.

3.5.3.3 *Dynamic reassignment services*

One of the essential features which mobility offers a user is the ability to receive and/or originate a call wherever he may be located. This concept implies the need for dynamic call reassignment services to track the whereabouts of the user in both space and time.

3.5.3.4 *Conversational services*

Conversational services in general provide the means for bidirectional dialogue communication with real-time (no store-and-forward) end-to-end information transfer from user to user or between user and host (e.g. for data processing). The flow of the user information may be bidirectional symmetric, bidirectional asymmetric and in some specific cases (e.g. such as video surveillance), the flow of information may be unidirectional combined with a signalling/control link in the reverse direction.

Examples of mobile conversational services are telephony, videotelephony, teleconference and data transmission, and short connectionless text messages.

3.5.3.5 *Messaging services*

Messaging services offer user-to-user communication between individual users via storage units with store-and-forward, mailbox and/or message handling (e.g. information editing, processing and conversion) functions.

Examples of mobile messaging services are message handling services and mail services for images, text and audio information.

3.5.3.6 *Retrieval services*

The user retrieval services can retrieve information stored in information centres and in general provided for public use. This information will be sent to the user on his demand only. The information can be retrieved on an individual basis. Moreover, the time at which an information sequence is to start is under the control of the user.

Examples are mobile retrieval services for image, audio information, and archive information.

3.5.3.7 *Distribution services without user individual presentation control*

These services include broadcast services. They provide a continuous flow of information which is distributed from a central source to an unlimited number of authorized receivers connected to the network. The user can access this flow of information without the ability to determine at which instant the distribution of a string of information will be started. The user cannot control the start and order of the presentation of the broadcast information. Depending on the point of time of the user's access, the information may or may not be presented from its beginning.

Examples are mobile broadcast services for image, text and audio programs.

3.5.3.8 *Distribution services with user individual presentation control*

Services of this class also distribute information from a central source to a large number of users. However, the information is provided as a sequence of information entities (e.g. frames) with cyclical repetition. So, the user has the ability of individual access to the cyclical distributed information and can control the start and order of presentation. Due to the cyclical repetition, the information entities selected by the user will always be presented from its beginning.

One example of such a service is teletext.

3.5.3.9 *Addressed one-way services*

Services of this class distribute information from a control source to a large number of users. However each message is addressed to one or more users in the group.

Examples of such services are one-way voice, text, audio and video, and radio paging without receipt.

### 3.5.4 *Types of information*

The following types of information should be capable of being carried by the FPLMTS:

| | |
|---|---|
| Voice | (A or $\mu$-law) |
| Audio | (3.1/7/15 kHz, including voice band modems, DTMF, etc.) |
| Text | (ASCII, etc.) |
| Image | (Variable resolution up to 1000 dpi, color) |
| Video | (Limited motion color) |
| Signalling | (Variable data rate) |
| Data | (Asynchronous and synchronous at various bit rates) |

It should be possible to carry combinations of these information types as appropriate.

### 3.5.5 *Description of network services*

Telecommunication services can be divided into two broad categories:

- basic services and
- supplementary services

Basic services are modified or supplemented by supplementary telecommunication services. Consequently, supplementary services cannot be offered to a customer as stand-alone services. They must be offered together with or in association with a basic telecommunication service. The same supplementary service may be common to a number of telecommunication services.

These basic and supplementary services are further subdivided into:

- bearer services
- teleservices

Bearer services provide the capability for the transmission of signals between user-network interfaces. Teleservices provide the complete capability including terminal equipment functions, for communication between users according to protocols established by agreement between administration and service providers. The teleservices utilize the capabilities of one or more bearer services.

For each type of service, bearer, teleservice and supplementary service there will be a set of attributes which specify the characteristics of the service.

The services which should be offered by the FPLMTS are described in the sections which follow. Many of them are based on CCITT definitions contained in the I.200 series of recommendations. The text identifies aspects of the services which may require modification to enable support within the FPLMTS. FPLMTS, in their ability to support subscriber mobility, will support additional services that do not exist within the fixed network.

As new telecommunication services are defined in the ISDN, it should be verified whether these can be made available to mobile users by means of new FPLMTS services or via service/network interworking with existing FPLMTS services.

Due to spectrum limitations, some of the services available in the ISDN may have to be offered in a slightly different manner in the FPLMTS (e.g. 64 kbit/s ISDN speech to be transmitted at bit rates lower than 16 kbit/s.)

3.5.5.1 *Bearer services*

The constraints imposed by radio transmission, spectrum availability and economics make it difficult to provide full ISDN B channels and D channels with an acceptable grade of service. Lower bit rate channels (or sub-rate channels) should be defined for the FPLMTS equivalent to the B (bearer) channel and the D (signalling) channel. In the FPLMTS, the I (information) and the C (control) channels have been identified to refer to the lower rate channels offering a functionally equivalent service to the B and D channels respectively.

Provision of new bearer services is possible when the protocol is based on the D channel protocol.

3.5.5.2 *Circuit - mode bearer services*

Bearer services can be defined over a range of bit rates.

Circuit-mode N kbit/s unrestricted,
8 kHz structured bearer service category,
where for example N = 8, 16, 32, 64, (2x64), 384, 1536 and 1920.

Bearer services with data rates < 64 kbit/s (sub-rate channels) can be used. Bearer services at data rates < 8kbit/s require further study but may be important in satellite applications.

ISDN bearer services described in CCITT Recommendations I.231.1, I.231.5, I.231.6, I.231.7 and I.231.8 correspond to data rates of 64, (2x64), 384, 1536 and 1920 kbit/s respectively.

The data rates for circuit-mode bearer services depend on the mix of services, spectrum availability and market demand and requires further study. It is likely that in initial implementations data rates greater than 64 kbit/s will be restricted to indoor environments. As technology improves higher bit rates may be possible and coverage may be increased.

Circuit-mode N kbit/s, N = 8, 16, 32 and 64
8 kHz structured bearer service category,
usable for speech information transfer ISDN service.

CCITT Recommendation I.231.2 corresponds to N = 64 kbit/s.

This bearer service is similar to the unrestricted service discussed above except that FPLMTS and the fixed network may use processing techniques appropriate for speech. Hence, bit integrity is not assured.

Circuit-mode 64, 32, 16 kbit/s and lower rates,
8 kHz structured bearer service category,
usable for 3.1 kHz audio information transfer

CCITT Recommendation I.232.3 defines a 64kbit/s service. Performance at 32 kbit/s, 16 kbit/s and lower rates requires further study.

This bearer service is suitable for modems and telefax applications as well as speech.

3.5.5.3 *Packet-mode bearer services*

Virtual call and permanent virtual circuit bearer service category-B channel (CCITT Recommendation I.232.1) or I channel

These services offer access to packet-switched data services.

The user information access channel within the FPLMTS may be a sub-rate channel. Maximum packet size and quality of service may be restricted. Further study is required to determine how the benefits of packet service can be given to FPLMTS data users.

Connectionless packet bearer service category on a D channel (CCITT Recommendation I.232.2) or C channel

The access channel in the FPLMTS may be a sub-rate D channel.

User signalling bearer services category (CCITT Recommendation I.232.3).

### 3.5.5.4 *Teleservices*

FPLMTS should support the teleservices listed below. These include teleservices derived from Figure C-2/I.210 of CCITT Recommendation I.210 and a variety of additional services.

Many of the services listed are based on definitions from CCITT Recommendations with appropriate modifications to suit the FPLMTS.

a) Telephony

The telephony service provides users of the FPLMTS with the ability for real-time two-way speech conversation. The service will be based upon CCITT Recommendation I.241.1 appropriately modified for application to the FPLMTS. Application to FPLMTS needs further study.

b) Programme sound

The programme sound service provide users of the FPLMTS with the ability to deliver information with sound programme quality.

c) Text

Text teleservices are outlined in the CCITT X.400 series of Recommendations Application to FPLMTS needs further study.

d) Teletex

The teletex service provides users of the FPLMTS with the ability to exchange office correspondence in the form of documents containing teletex coded information on an automatic memory-to-memory basis. (CCITT Recommendation I.241.2)

e) Paging

FPLMTS should be able to provide paging services integrated with telephony and data services, to the extent permitted by individual administrations. Mobile satellites may offer wide area paging beyond the range of terrestrial systems.

FPLMTS should be able to provide paging services in several different modes:

- "open loop transmission" (i.e. page sent to a device that does not transmit any acknowledgment upon reception of the message)

- "closed loop transmission" or "with network acknowledgment" (i.e. page sent to a device that will acknowledge reception)

- "with user acknowledgment" (i.e. the acknowledgment will be sent when the user indicates to the device that he has received the message)

The sender of the page should have the possibility of choosing the preferred mode (whether the sender will receive an acknowledge or not, will depend upon the hardware of the pager and of the propagation conditions).

f) Videotex

The videotex service will provide a retrieval service for text and image information. The service should be based on CCITT I.241.5 Recommendations suitably modified for application to the FPLMTS.

g) Telefax

The telefax service will enable users to exchange correspondence in the form of documents containing telefax coded information on an automatic memory-to-memory basis via the FPLMTS. Standards for this service should be based on CCITT Recommendation I.241.2 suitably modified for application to the FPLMTS.

h) Programme video

The programme video service will enable users to deliver video via the network. It is likely that all programme video carried via the FPLMTS will be compressed.

i) Video surveillance

The video surveillance service will provide users of the FPLMTS with the ability to deliver video for remote surveillance purposes.

j) Video telephony

The video telephony service will provide users of the FPLMTS with the ability for real-time two-way combined speech and video conversation via the network. It is likely that all video telephony carried via the FPLMTS will involve compressed video.

k) Data

Several synchronous and asynchronous data services are standardized on the PSTN including 300, 1200, 2400, 4800 and

9600 bit/s. Issues needing resolution include interfaces according to U, I, and X Recommendations, interworking with fixed networks and error control on the radio link.

The FPLMTS should be designed so that under favourable circumstances services requiring high bit rates can be provided. For instance if the mobile terminal is stationary, or moving slowly, and is close to a base station which is not heavily loaded otherwise, it may be possible to provide services up to the primary ISDN rate of 1536 or 1920 kbit/s. Under less favourable circumstances, e.g. mobile terminals at greater distances from the base station or when the base station is carrying a heavy load of traffic, then the services may be restricted to those using lower rates.

l) Teleconference

The teleconference service will provide users of the FPLMTS with the ability for real-time two-way speech, data and/or video between two or more locations simultaneously. It is likely that all video information carried via the FPLMTS will be compressed.

m) Short messages

These connectionless services allow the exchange of messages of limited length (say one or several 32 byte blocks) between a storage system connected to the fixed network and a mobile station, or between mobile stations, in real-time. It can be a point-to-point or point-to-multipoint service.

The teleservices defined above are divided into two categories: primary and secondary as listed below:

Primary:

Telephony
Text
Teletex
Paging
Videotex
Telefax
Data
Short Message

Secondary:

Programme Sound
Teleconference
Programme video
Video surveillance
Video telephony

Any implementation of an FPLMTS should support as minimum, the primary teleservices. The degree to which the secondary teleservices are also supported by the FPLMTS may vary between administrations and should be subject to further study.

3.5.5.5 *Supplementary services*

Supplementary services for mobile systems are under discussion in CCITT. It is expected that CCITT Recommendations Q.1011 through Q.1019 describing some supplementary services will be issued during the 1988-92 study period. Examples of supplementary services are listed in Table 1/I.250 in CCITT Recommendation I.250.

The following supplementary services support mobility:

a) Point-to-multipoint

FPLMTS should provide this service for dispatch, group calling, closed user groups and other applications, to the extent permitted by individual administrations.

b) Separation of answering from alerting

In current public telecommunication systems, the alerting function always resides in the same terminal used to answer the call. However, in the FPLMTS, it is envisaged that the device on which the alert is received, e.g. pager, personal station (PS), etc., is not necessarily the one used to answer the call. The called party will be able to use any terminal of his choice (e.g. telephone or mobile station (MS /PS) to answer the incoming call. This implies that the delivery of a signal to an alerting device is not a completed activity, rather, just a part of the total activity associated with establishing a call.

This service concept could have implications on the sequence of call-establishment signals as well as call completion time delays. The details of this service as well as user acceptability need further study by a wide range of experts.

c) Charging service

FPLMTS should be able to decide the distribution of the charges between the parties involved with a particular call based on the personal telecommunication service profiles associated with each PTN used by these parties respectively.

The paying party (or parties) should be able to receive the respective charge information before, during, or after each call when it is feasible.

This charging service will provide all users the option to obtain charge information of a particular call without compromising the other users' privacy.

d) End-to-end encryption

The FPLMTS should support the use of end-to-end encryption associated with any teleservice which uses an unrestricted circuit-mode or packet-mode bearer service. As a supplementary service, FPLMTS should also support end-to-end encryption of speech by the use of an unrestricted circuit-mode bearer via the ISDN. This service may have an impact on the ISDN and requires further study.

e) Mobile-to-base station encryption

The FPLMTS should also support mobile-to-base station encryption, which in some cases will offer sufficient protection whilst being easier to implement than end-to-end encryption.

f) Location

The provision of information to the calling or called party as to the location of the corresponding party. (See also 3.5.3 and 3.5.5.5c.)

g) PTN

The provision of a PTN service as defined in 3.4 to a user including the feature offered by the PTN service profile.

h) Automatic message box status indication

Automatic message box status indication (e.g. new message, urgent message, empty) reduces loss of communication whilst a user is moving.

3.5.5.6 *Service attributes*

Telecommunication services are classified using their static characteristics described by attributes. Service attributes for ISDN services are described in CCITT Recommendation I.210. The service attributes for FPLMTS can be grouped into 4 categories:

Information transfer attributes
Access attributes
General attributes
Mobility attributes

Table II indicates some possible values for the FPLMTS service attributes.

# Table II Possible FPLMTS service attributes

| Attributes (Note 1) | Possible values of attributes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **A. Information transfer attributes** | | | | | | | | | | |
| A1. Information transfer mode | Circuit | | | | | | | | | Packet |
| A2. Information transfer rate (*: specific to FPLMTS) | Bit rate kbit/s | | | | | | | | | Throughput |
| | 8 * | 16 * | 32 * | 64 | 2x64 | 384 | 1536 | 1920 | Other values for further study | Options for further study |
| A3. Information transfer capability | Unrestricted digital information | Speech | 3.1 kHz audio | 7 kHz audio | 15 kHz audio | Video | Others for further study | | | |
| A4. Structure | 8 kHz integrity | Service data unit integrity | Unstructured | TSSI (2) | RDTD (2) | | | | | |
| A5. Establishment of communication | Demand | Reserved | Permanent | | | | | | | |
| A6. Symmetry | Unidirectional | Bidirectional symmetric | Bidirectional asymmetric | | | | | | | |
| A7. Communication configuration | Point-to-point | Multipoint | Broadcast | | | | | | | |
| **B. Access attributes** | | | | | | | | | | |
| B1. Access channel and rate | I*, C*, D(16), D(64), B, H0, H11, H12 (*: specific to FPLMTS) | Others for further study | | | | | | | | |
| B2. Signaling access protocol (all layers) | For further study (specific to FPLMTS) | | | | | | | | | |
| B3. Information access protocol attributes | For further study (specific to FPLMTS) | | | | | | | | | |
| B4. Higher layer protocols | For further study (specific to FPLMTS) | | | | | | | | | |
| **C. General attributes** - supplementary services provided - quality of service - interworking - OA + M | For further study (specific to FPLMTS) | | | | | | | | | |
| **D. Mobility attributes** - location - handovers - user profile (PTN) - alerting - call completion | For further study (specific to FPLMTS) | | | | | | | | | |

Notes:
1. Attributes are intended to be independent of each other.
2. TSSI: Time Slot Sequence Integrity
   RDTD: Restricted Differential Time Delay
3. This table follows Figure 8-2/I.210 (CCITT) except where noted.

3.6 *Basic speech quality*

The quality of speech services in FPLMTS should be comparable to that of the PSTN/ISDN as far as practicable.

The effective utilization of the frequency spectrum is an important factor for FPLMTS and, accordingly, it is necessary to develop speech coding methods that provide high quality speech at low bit rates. The practical design of the speech coder will be strongly influenced by the requirement to achieve reasonable overall transmission delay. This overall delay should also take into account delay introduced by the RF channel and signal processing.

Speech services that are sensitive to delay may need to be redefined.

The quality of speech supported within the FPLMTS should be nominally that recommended in the CCITT P series Recommendations. However it is acknowledged that in some applications where low bit rate coding is employed some minimal degradation of speech quality may occur.

3.7 *Security*

FPLMTS should provide a level of security comparable to that of the PSTN/ISDN and public data networks. Cryptographic techniques can provide both privacy and authentication. Due to the basic nature of the radio transmission, added protection against unauthorized access to the system (authentication) must be provided to protect customers and the integrity of the system. An authentication method is outlined in CCITT Recommendation X.509. The use of the PTN service provides another means for authentication. Application to FPLMTS requires further study.

FPLMTS may be capable of offering additional encryption of user information but any such facility should not increase the costs incurred by mobile subscribers who do not require such facility.

It should be possible for the users themselves to provide end-to-end encryption, subject to the technical limitations of the network.

3.8 *Quality of service*

The quality of service offered by the FPLMTS should be comparable to that of the PSTN/ISDN and public data networks as far as practicable.

Consideration will need to be given to maintaining quality of service during handover between cells and any implications from this on cell size, frequency requirements, protocols, etc.

Mobile satellite systems have a number of characteristics which are different from land mobile systems such as wide area coverage and propagation delays on the order of 0.3 s or more.

To maintain the quality of services for Group 3 and Group 4 telefax machines, additional error control facility for the radio communication path may be required.

## 4. System architectures and scenarios

### 4.1 *System architecture*

The basic structure for the FPLMTS can be provided by a system architecture which evolves from present-day fixed and mobile networks toward the goal of world-wide communications mobility for people wherever they may be, at home or away, in transit (aircraft, trains, cars, ships), etc., with services interworkable with those offered by the fixed networks such as PSTN/ISDN. FPLMTS may comprise one integrated system or several separable systems, as further study will indicate.

The support of service interoperability will require the provision of network functions and the definition of signalling protocols for use both over the radio system signalling channels and within the fixed network. CCITT has developed a three-stage method for the development of protocols (see CCITT Recommendation I.130, Blue Book), used effectively in the development of the ISDN, which may be useful for the design of FPLMTS.

#### 4.1.1 *Service access*

The PTN service provides a flexible means of accessing FPLMTS services as described in 3.4.

The FPLMTS should provide universal personal telecommunication services through a universal service access mechanism such as PTN, by which new technology and various regional constraints may be accommodated [De Brito, 1981]. The FPLMTS should perform service origination and termination regardless of user location within the FPLMTS or the PSTN/ISDN.

Given a PTN, any user terminal can be used as a means for access; consequently, the terminal may vary as access is provided through either mobile or fixed means.

A user-network interface standard needs to be defined so that user terminals will be transparent to transmission technology.

#### 4.1.2 *Description of interfaces*

The major functional components of the FPLMTS are shown in Fig. 3 (This is not intended to represent a specific implementation scenario).

These functional components in turn define a group of interfaces (1-10) which may be physical or conceptual. Furthermore, these interfaces should be based on appropriate CCITT Recommendations after unique requirements of FPLMTS are incorporated. The generic radio link interface 1 will be discussed in more detail in 4.3.

A possible partition of basic MS/PS signalling functions is shown in Fig. 4, which consists of:

- Call Control;

- FPLMTS Call Control Adaptation;

- Mobility Management; and

- Channel and RF Transmission Management.

The signalling reference points between these functions are designated as S/R, Xm, Sm and Um, and are shown in Fig. 4 These correspond to the same designations as in CCITT Recommendation Q.1061.

Call Control functions are those standard call controlling functions available in any CCITT Standard Terminals (e.g. X.25 Data Terminals, ISDN User Terminals, PABX etc.) or any future FPLMTS terminals. FPLMTS Call Control Adaptation functions are those functions necessary to convert standard call control signalling into call control signalling appropriate in the FPLMTS environment. Mobility Management functions are those functions necessary to support the mobility of user and terminals. Channel and RF Transmission Management includes those functions associated with providing a wireless physical connection between the user terminal and a base station, such as selecting the channel coding, controlling transmitter power, seizing a channel, changing a channel, etc.

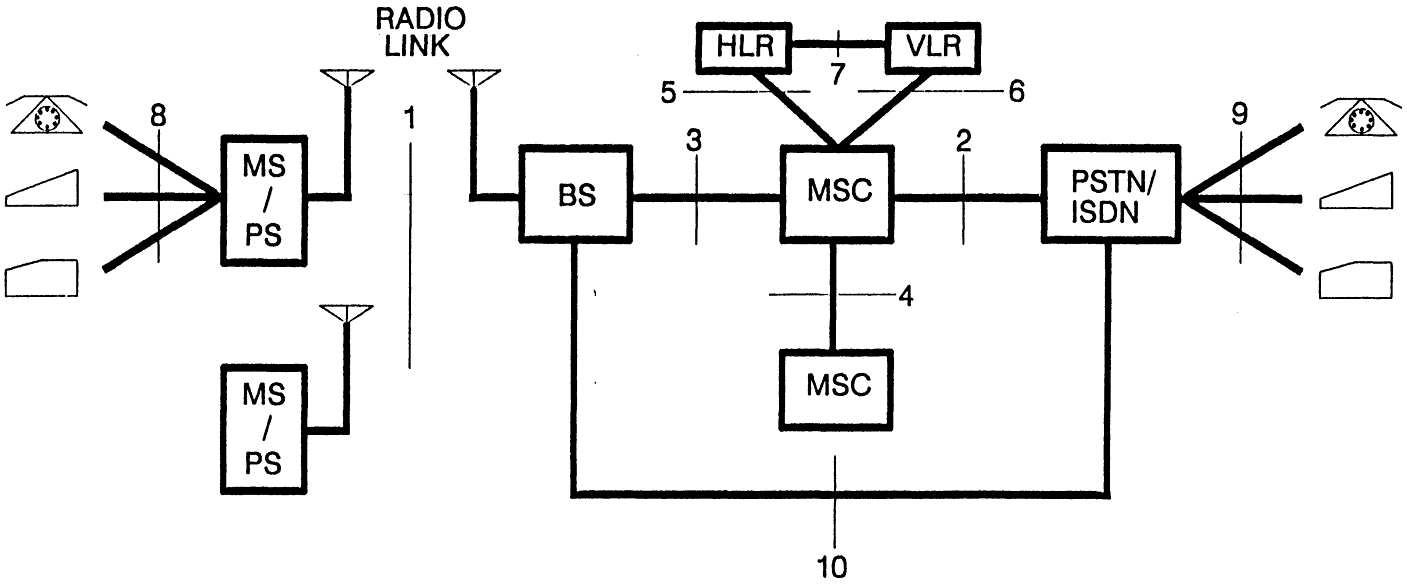
4.1.3 *Integration with mobile satellite systems*

FPLMTS users roaming over a wide area may access (directly or indirectly) either terrestrial systems or mobile satellite systems (See Figs. 5 and 6, also see Report 1177.) An architectural feature could be automatic diversion to mobile satellites for FPLMTS service when the user is beyond the range of terrestrial system coverage. Mobile satellites may also support:

- A satellite paging function which could reduce the amount of location registration data to be transferred.

- Paging terrestrial mobile users beyond the range of the terrestrial system. The equipment required for this one-way function is simpler than that for a two-way mobile satellite function.

- Linking remote base stations or where temporary (e.g. emergency) system extension is needed.




MS — Mobile Station
PS — Personal Station
BS — Base Station
MSC — Mobile Services Switching Centre
HLR — Home Location Register
VLR — Visitor Location Register

**Fig. 3 Major Functional Components and Interfaces of the FPLMTS**

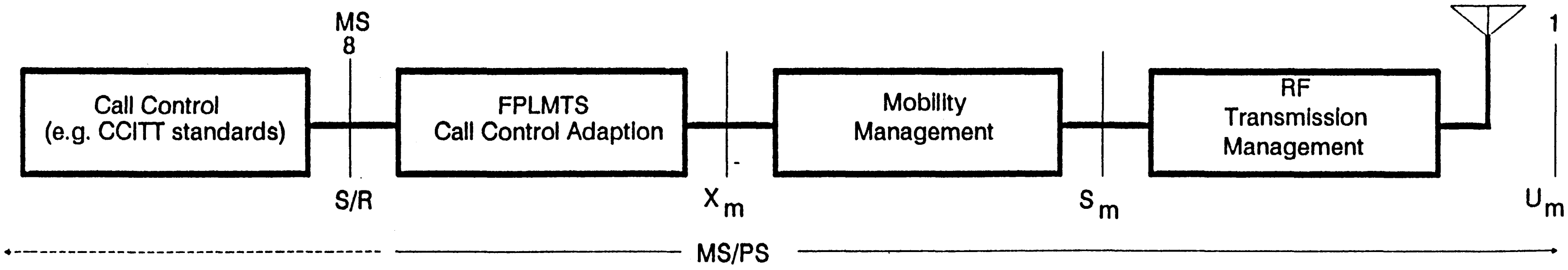
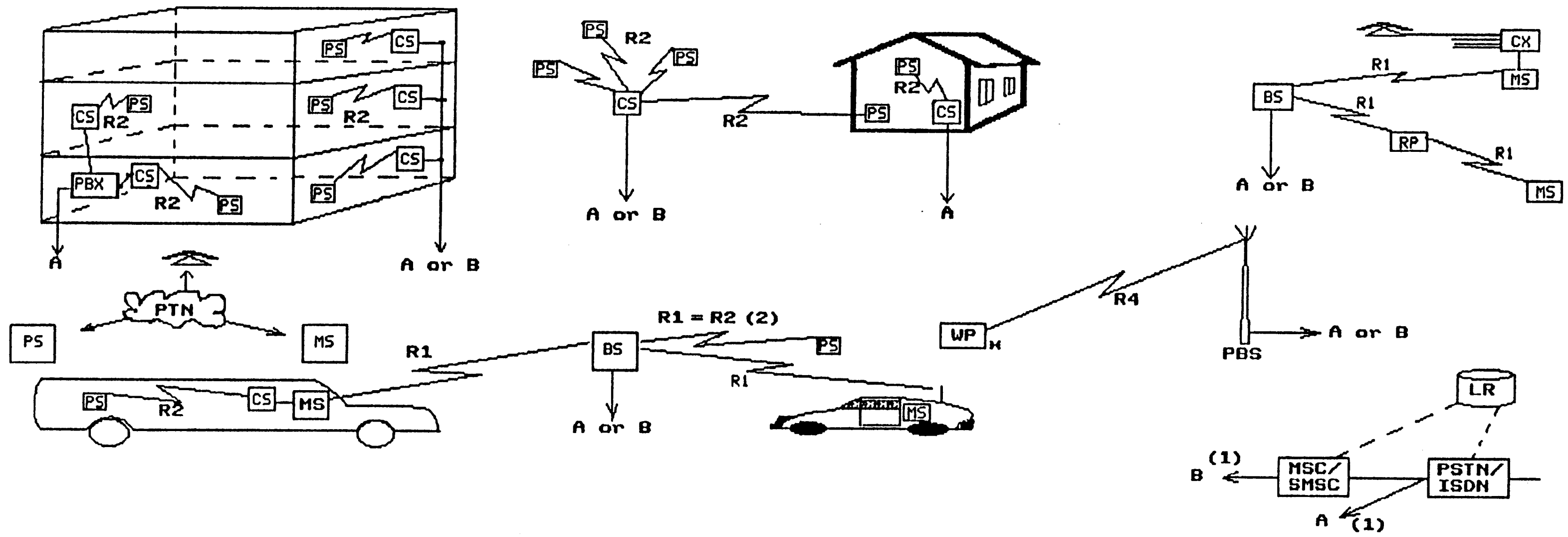



**Fig. 4 MS/PS Signalling Reference Points**



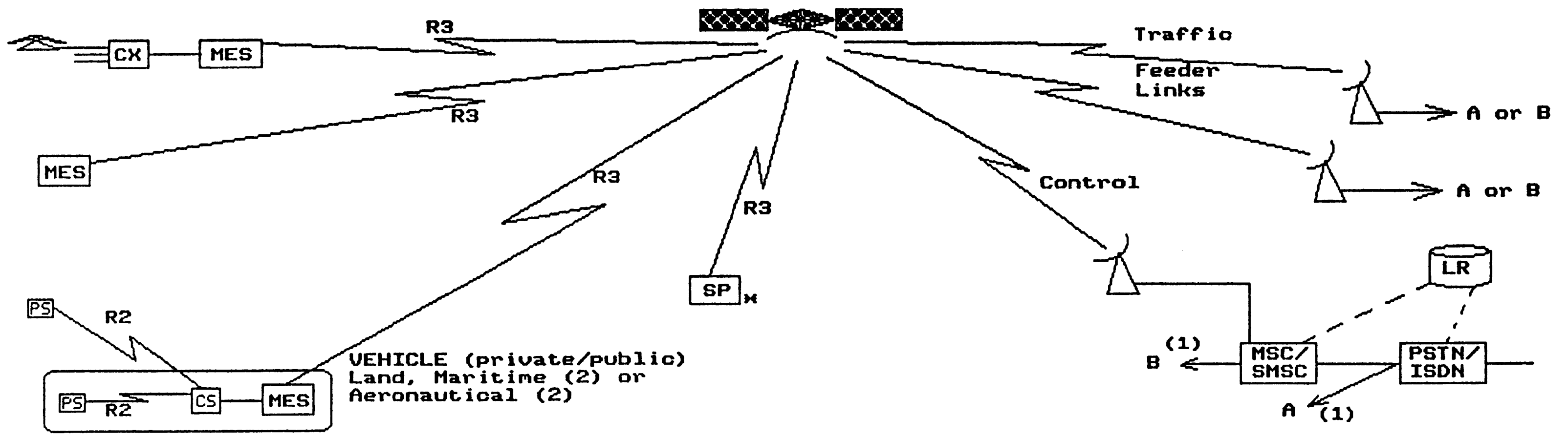

R1–R4: Radio Interfaces
PS: Personal Station (R2)
CS: Personal Base Station (Cell Site for PSs)
MS: Mobile Station (R1)
BS: Base Station (for MSs)
MSC: Mobile services Switching Centre
SMSC: Satellite Mobile services Switching Centre
LR: Location Register
CX: Small rural exchange, etc.
RP: Repeater
PTN: Personal Telecommunications Number Service
PBS: Paging Base Station
WP: Wide Area Pager (R4)
[telephone symbol]: Telephone

Note (1): Access to and the scope of the location registration functions will vary with system evolution and network operator requirements. This is reflected in network interfaces A and B.

Note (2): In some implementation scenarios R1 may equal R2.

*: Can be co-located/integrated with the PS.

**Fig. 5 Scenario for Personal Communications with FPLMTS (Terrestrial Component)**




R1–R3: Radio Interfaces
PS: Personal Station (R2)
CS: Personal Base Station (Cell Site for PSs)
MES: Mobile Earth Station
SP: Satellite Pager (R3)
MSC: Mobile services Switching Centre
SMSC: Satellite Mobile services Switching Centre
LR: Location Register
CX: Small rural exchange, etc.
(symbol): Telephone

Note (1): Access to and the scope of the location registration functions will vary with system evolution and network operator requirements. This is reflected in network interfaces A and B.

Note (2): Terrestrial based systems have different radio interface requirements from R3 which need to be considered.

✱: Can be co-located/integrated with the PS.

**Fig. 6 Scenario for personal communications with FPLMTS (Satellite component)**

4.2 *Scenario for personal communications within FPLMTS*

A scenario for the evolution and implementation of personal communications is illustrated (Figs. 5 and 6) and tabulated (Table III). These figures and the table provide a quick survey of the arrangement of facilities and typical dimensions for such a scenario.

The scenario discussed identifies a broad approach to evolving personal communications. It presents a preliminary framework for understanding the implications of other areas of the Report and a basis for identifying areas of commonality.

Some of the distinguishing characteristic assumptions of high density PS communications are small coverage area per personal base station (CS) and less dependence on a single base station to minimize shadowing.

In Table III, the dimensioning of cell areas, traffic, antenna height and other parameters are typical values averaged or estimated by various administrations. The dimensions are not maximum or minimum values which might be required in some circumstances.

As cell areas are reduced, the number of handover increases. The subjective user tolerance is dependent on the frequency and duration of handover breaks. This may limit the ultimate minimum cell area.

Station output powers are shown as an average power value which is a fair measure of range requirements. Peak and average values are normally the same for systems with FDMA, but the peak value could be higher for Time Division Duplex (TDD) and TDMA "duty cycle" systems.

**Table III**
**Example of the characteristics for personal communications within FPLMTS**
**(High density area)**

| CHARACTERISTIC | TYPE OF STATION | | |
|---|---|---|---|
| | Mobile | Personal Station (PS) (1) | |
| Cell Plan | MS Outdoor | PS Outdoor | PS Indoor |
| Cell Area: | (min) 0.5 - 1 $km^2$ | (typ) 16000 $m^2$ | (typ) 600 $m^2$ |
| Base Station Antenna Height | 50 m | <10 m | <3 m (2) |
| Service Area Reliability | 90% | >90% | 99% |
| Base Station Installed indoor/outdoor | No/Yes | Yes/Yes (3) | Yes (3)/Yes |
| Voice traffic per station (6) | 0.10 E | 0.04 E | 0.20 E |
| Non-voice traffic per station | 0.05 E | 0.004E | 0.11 E |
| Voice traffic per $km^2$ (6) | 500 E | 1500 E | 20000 E (4) |
| Non-voice traffic per $km^2$ | 82 E | 150 E | 5000 E (4) |
| Blocking | 2% | 1% | <0.5% |
| Station: (5) Volume | Vehicle mounted | <~200 $cm^3$ | <~200 $cm^3$ |
| Weight | or portable | <~200 g | <~200 g |
| Highest Power | 5W | 50 mW | 10 mW |

(1) The same PS provides access to cell plans PS outdoor and PS indoor, and also to cell plan MS if MS and PS have the same radio interface (i.e. R1 = R2).

(2) Or leaky feeder

(3) Usual case

(4) Per floor

(5) A range of terminal types will be available to suit operational and user requirements.

(6) See Section 5.

## 4.3 *Radio interface considerations*

### 4.3.1 *Interface types*

From the scenario of Fig. 5 and Table III, the radio interface considerations are:

- The personal station (PS) interface R2 is used in two separate cell plans, one for mainly outdoor and one for mainly indoor coverage. The two cell plans may use different sets of frequencies within the same band.

- A separate interface R1 and separate frequencies may be envisaged for the mobile station (MS) as distinct from the personal station. However, a common radio interface (R1 = R2) may be possible, as well as a common frequency band for the different cell plans.

- The radio interfaces should be designed to allow different applications to use the same interface where this can be shown to be technically and economically feasible.

- If the same radio interface cannot be used for all applications then the individual interfaces should have maximum commonality to allow interworking with the minimum extra complexity.

- With the low transmit powers considered for the personal station, coexistence with other services (e.g. private wireless PABX) is a possible consideration.

- It is generally assumed that the location of the personal station changes slowly with respect to the personal base station.

- The wide area paging interface R4 is an additional signalling interface used for alerting (e.g. paging) a station in the case of a mobile terminated call.

- When using R4, the location area will conform to the paging area of the paging base station.

The scenario of Fig. 6 introduces interface R3, which is integrated in the signalling functions of FPLMTS.

- Interface R3 is a satellite communications interface used for both signalling and traffic.

- When using R3 for alerting (e.g. paging), the location areas will conform to the coverage areas of the satellite station.

Real time interaction with CCITT Common Channel Signalling No. 7 (CCS7) requires special consideration, especially when alerting and answering are considered to be separate functions joined by CCS7 (see 3.5.5.5).

As shown in Figs. 5 and 6, a mobile station (MS) or a mobile earth station (MES) can be envisaged to provide a tandem link to personal stations (PS) inside a vehicle.

Other interfaces may be required for terrestrial aeronautical and maritime mobile systems.

A common world-wide radio interface may be a desirable but not essential goal to achieve mobility, although it may be desirable from the point of view of cost reduction and wider availability of equipment.

### 4.3.2 *Signalling protocols*

The signalling protocols should support ISDN compatible services and services specific to the FPLMTS, and should facilitate interworking between PSTN/ISDN and FPLMTS. Studies and refinements of telecommunications services definitions should be undertaken for the development of signalling protocols (e.g. requirement to support packet data on control channels).

Reference configurations and signalling protocol models should be aligned as closely as possible with OSI and ISDN reference models. In addition, account should be taken of signalling protocols developed for current and planned mobile systems including cellular systems, cordless telephones, mobile satellite systems and terrestrial air-to-ground systems.

Signalling protocols must be consistent with the propagation and spectrum constraints of the radio environment. However, the functionality of ISDN signalling should be maintained to the maximum extent practicable.

The signalling functions over the radio interface is envisioned to consist of three layers.

Signalling Layer 1 should provide a reliable RF connection between a base station and a mobile/personal station. Examples of functions are RF channel structure, RF modulation and demodulation, framing/timing, power adjustment, etc.

Signalling Layer 2 should provide reliable signalling data link between a base station and a mobile/personal station.

Signalling Layer 3 should provide a reliable application message communication between a base station and a mobile/personal station. It can be subdivided into three functional entities: Call Control (CC), Mobility Management (MM) and RF Transmission Management (RT). The CC entity would contain the functionalities for support of basic and supplementary services

(Call Setup, Call Release, etc.). The MM entity would contain functions like Location Updating, PTN Attach/Detach, Authentication, etc. The RT entity would contain functions like Channel Assignment, Handover, Channel Release, Measurement Reporting, etc.

The details of the signalling protocols will be jointly studied and defined by both CCIR SG 8 and CCITT SGXI.

4.4 *System capabilities for a PTN service*

A personal telecommunication number (PTN) service which enables call connections, billings etc., on a personal basis is defined in 3.4.2.4.

In order to offer a PTN service, the following system capabilities are necessary:

- To provide a PTN number for each user,
- To admit registrations and dismissals of users to and from the system by the PTN number,
- To enable routing to the registered location by the PTN number,
- To charge on the basis of the PTN number,
- To authenticate an user by the PTN number.

In order to provide the PTN service, the following major topics should be considered:

- Traffic for PTN registration and dismissal of a person to the network and related aspects,
- Man-machine interface, including authentication,
- System operational aspect,
- Roaming service ability.

The CCITT Study Groups are investigating a broader application of the PTN service which covers both fixed networks and radio networks.

**5. Frequency considerations**

5.1 *General*

A fundamental goal in the design of a FPLMTS is the provision of adequate capacity to serve its intended customers. It is also important to ensure that the most efficient use of radio spectrum (maximum Erlangs of information transfer per MHz per $km^2$) is made.

To that effect, considerations on spectrum should take into account the traffic, the available and foreseeable techniques, the propagation characteristics and the timescale for meeting the users' needs to the greatest possible extent. All the techniques considered need to be balanced with particular attention to the cost, size, weight and power consumption of the mobile and personal stations.

## 5.2 *Users' needs*

The need for mobile communications available in any place and time is increasing rapidly.

An expansion rate as high as 100% a year has been experienced for current systems based on analogue technology, in a number of countries. It is expected that the number of subscribers to public mobile systems will exceed 10 million in 1990. With the introduction of digital technology it is foreseen that the penetration of mobile units in Europe and North America in the late 1990's will be around 5% of the population.

In addition demands for personal communications using lightweight portable equipment for both indoor and outdoor communications will increase considerably the penetration of public mobile communications. It is expected that this category of users will generate a need for worldwide roaming. The number and diversity of services is also expanding. Systems under consideration will include voice and non-voice services with similar levels of importance.

For all categories of customers, particularly those using personal stations, compatibility of the services provided by different networks is of primary importance. Commonality, particularly in frequency matters, is a very important factor for FPLMTS. Cost and technological factors are also of importance to make available cost effective and, when necessary, low weight, low power consumption equipment. Within a service area, a reliability of at least 90% is expected and may reach 99% for home and business applications.

## 5.3 *Traffic considerations*

### 5.3.1 *General*

The maximum demand for "personal" telecommunication services is in large cities where different categories of traffic can be found, i.e. that generated by mobile stations (MS), vehicle-mounted or portable and personal stations (PS), outdoor and indoor. The number of customers in these different cases may be estimated, with some variations, according to the nature of the cities.

The traffic generated by the paging service in FPLMTS has not yet been estimated but is considered proportionally insignificant.

The traffic of the Land Mobile Satellite Service has not been considered. It is relevant to Decision 81.

### 5.3.2 *Voice traffic*

It is estimated that in a traffic jam the number of vehicles per km of street length is around 600 if they are stationary or 350 if they are moving slowly. Assuming a mean value of 400 vehicles per km of street length, 50% of the vehicles equipped with a mobile station, each generating 0.1 E, the traffic density will be 20 E/km of street length or 300 E/km$^2$ for vehicle-mounted mobile stations on the street. Adding about the same amount of traffic for portable mobile stations carried by pedestrians, the combined traffic, for Mobile Stations (MS), would be around 500 E/km$^2$ in the most dense city areas.

The peak traffic density for personal stations outdoor is estimated at 1500 E/km$^2$, assuming 3000 pedestrians per km of street length, 80% penetration of the personal station and 0.04E/station.

For personal stations indoors the traffic may increase by a factor of 10 or more in a multi-storey office building. An estimation is 1 station per 10 m$^2$ active floor area with a traffic of 0.2 E per station. This corresponds to 20,000 E/km$^2$/floor.

It is estimated that the peak to mean ratio of traffic for pedestrians in busy streets of large cities has a value around 3.

### 5.3.3 *Non-voice traffic*

In the future, non-voice services will constitute an increasing proportion of total traffic. Some data services need more transmission capacity than a duplex voice channel , increasing the necessary spectrum. On the other hand, some non-voice services can be handled by using queuing procedures, which improve the spectrum utilization.

#### 5.3.3.1 *Mobile stations*

- Circuit-switched services are considered as being relevant mainly for vehicle-mounted MS. Telefax is an example of such a service. Assuming 3000 terminals/km$^2$, of which 15% are equipped with a telefax unit, a call holding time of 6 minutes per hour, per terminal; the estimated traffic amounts to 45 E/km$^2$.

Interactive data services are likely to employ packet transmission. The assumption is a cumulative channel occupancy of 15 s/hour for a hand portable (10 pages per hour with 8 kbit per page, at a transmission rate of 4.8 kbit/s) and 30 s/hour occupancy for a vehicular mobile (4.5 and 9 mE respectively). Assuming 5000 terminals per km$^2$ (3000 vehicular and 2000 portables), the estimated traffic amounts to 37 E/km$^2$ [Turner, 1986; Goodman et al., 1988].

5.3.3.2 *Personal stations outdoor*

Traffic generated by circuit-switched data services, eg. telefax, has been considered insignificant. Therefore, only short-message interactive data communications are considered in the present case.

The assumption is a cumulative channel occupancy of 5 s/hour (10 pages per hour with 8 kbit per page at a transmission rate of 16 kbit/s) corresponding to 1.4 mE/station.

Assuming 2400 stations/km of street length (37,500 stations/km$^2$), as in the case of voice, the amount of traffic would be 50E/km$^2$. To account for other data services, this estimate is increased by a factor of 3 to 150E/km$^2$. The non-voice traffic is then 10% of the voice traffic.

5.3.3.3 *Personal stations indoor*

For telefax application: assuming 25% of stations having a telefax and 6 minutes call holding time per hour, per telefax terminal; the estimated traffic is 25 mE per station i.e. one-eighth of the voice traffic, or 2500 E/km$^2$.

For interactive application: considering all stations are using this application and assuming 20 interactive sessions per hour, with a cumulative channel occupancy of approximately 2 s per session, we arrive at 0.01 E/station, equivalent to 1000 E/km$^2$. In order to take account of contention due to packet transmission, a factor of 2 is assumed, leading to 2000 E/km$^2$.

In total, taking into account batch data application, data base retrievals (10% overhead) a total amount of 5000 E/km$^2$ is assumed for non-voice services indoor.

5.4 *Spectrum Requirements*

5.4.1 *Bandwidth estimation method*

A general equation can be derived for circuit-switched services giving the bandwidth 'BW' (MHz), assuming a relatively uniform traffic load over a reuse cluster of cells.

$$\mathbf{'BW' = 10^{-3}.F\,(a\,.\,E,\ P_b)\,.\,b\,.\,n}$$

where 'F' is the appropriate traffic formula (e.g. Erlang B or C for voice). 'E' is the traffic load in Erlang/km$^2$, 'a' is the cell area in km$^2$, 'n' is the number of cells (channel sets) per reuse cluster, '$P_b$' is the blocking probability in percent, and 'b' is the equivalent bandwidth per duplex channel in kHz, including signalling and other overheads.

5.4.2 *Technological and other factors influencing overall spectrum requirements*

There are many factors that affect the variables in the bandwidth calculation equation above and hence the overall spectrum requirements.

5.4.2.1 *Bandwidth of a duplex channel*

The bandwidth of a duplex channel 'b' can be reduced significantly by using low bit rate speech codecs. In addition, the use of packet transmission, digital speech interpolation (DSI) and adaptive system parameters offer the possibility of further reductions [Turner, 1986; Goodman et al., 1988]. In contrast, future demands for high quality speech or the requirement to support ISDN services with, for example, more stringent BER thresholds or limits of transmission delay would increase channel bandwidths, as would additional overhead e.g. for dynamic power control.

5.4.2.2 *Number of cells/cluster*

A decrease in the number of cells (channel sets) per reuse cluster 'n' could be achieved by a combination of micro diversity (space/frequency hopping) and macro-diversity, coupled with both inter-cell and intra-cell rapid handover procedures. The implementation of adaptive system techniques such as electronically steerable antennas, dynamic power control and "leaky feeders" (mainly for indoor cells) could also reduce the number of cells/cluster. However, non-ideal transmitter locations and imperfect cell geometry, combined with a need to carry less interference tolerant signals e.g. high-quality speech, would increase the number of cells/cluster. An increase in service area reliability and/or adverse propagation conditions could also increase the effective cluster size.

5.4.2.3 *Cell area*

Rapid handover procedures are essential if cell areas 'a' are to be reduced and the consequent improvements in spectrum efficiency realized. However, non-ideal cell geometry would reduce the overall improvement.

5.4.2.4 *Blocking probability.*

The choice of blocking probability '$P_b$' for any particular cell type or environment is a quality-of-service target. However, a change in '$P_b$' will only marginally affect the overall spectrum requirements.

5.4.2.5 *Trunking efficiency*

Trunking efficiency is influenced by traffic patterns, services and system design. By using techniques such as dynamic channel allocation, trunking efficiency and hence spectrum utilization can be improved. However, other factors such as multiple operators splitting the spectrum allocation into different blocks, would reduce trunking efficiency and increase spectrum demands.

5.4.3 *State of techniques*

5.4.3.1 *General*

The design of systems for carrying traffic to mobile users is directly related to spectrum efficiency and so the system parameters should be optimized to that effect.

Any improvement in spectrum efficiency should be balanced against system design constraints e.g. power consumption and cost effectiveness. A number of system parameters are considered below.

5.4.3.2 *Speech transmission*

A transmission bit rate of 16 kbit/s or below is desirable to improve spectrum utilization. Good quality codecs with robustness and low delay are required. Linear predictive coding (LPC) techniques combined with adaptive quantization and adaptive prediction offer, at this point in time, the most attractive possibilities for FPLMTS in terms of speech quality at low bit rates. For fast fading channels, the most efficient and economical system would have matched speech and channel codings.

The power consumption and size of codecs is particularly critical for personal stations.

5.4.3.3 *Data transmission*

Practical and frequency economy considerations would probably limit the allowable data rate to below 1 Mbit/s for mobile stations. However, megabit rates may be useful and practicable for short range systems within buildings.

For relatively narrowband transmission (e.g. less, or of the order of the coherence bandwidth) and for fast-fading, forward error correction (FEC) is effective to improve spectrum efficiency and to reduce the RF output power for high quality transmission (average BER is less than $10^{-3}$ to $10^{-4}$). For relatively low quality transmission (average BER is $10^{-2}$ or more), FEC gives no improvement and can reduce spectrum efficiency. For the slowly fading channel, error detection and automatic repeat request (ARQ) may be more effective than FEC.

5.4.3.4 *Modulation and equalization*

Digital modulation schemes should be used which combine low bandwidth requirements with good C/I and C/N tolerances. Modulation techniques having transmission efficiencies in excess of 1 bit/s/Hz are desirable candidates for FPLMTS. Signal processing techniques such as adaptive equalizers might be necessary for wide band transmission.

5.4.3.5 *Channel coding*

Channel coding combined with interleaving is a spectrally efficient technique to provide adequate transmission quality, particularly for mobile applications. Channel coding techniques can be divided into two families: block codes and convolutional codes. Block codes, such as Reed-Solomon, are used for both error detection and correction, while convolutional codes are primarily used for error correction. Fade duration, inter-fade interval and random error rate can influence the choice of channel coder.

5.4.3.6 *Multiple access*

Multiple access techniques, such as FDMA, TDMA and CDMA, should be considered for FPLMTS. FDMA/TDMA schemes for second generation cellular svstems have been adopted in both Europe, North America and Japan. (See Report 1156).

FPLMTS could provide a mixture of narrowband and broadband services. A flexible multiple access technique and an efficient management system for the traffic associated with the various different services are both desirable to maximize the overall spectrum efficiency of FPLMTS. In all cases, demand assignment will improve spectrum efficiency.

5.4.3.7 *Adaptive techniques*

In order to improve performance, systems may adapt such parameters as channel bit rate, bandwidth and frequency/time/coding arrangements, and use techniques such as diversity, channel assignment and multipath equalization to adapt to actual propagation, interference and traffic conditions. Such adaptive techniques also have the potential to minimize radio network planning requirements, especially as cells become smaller. [Acampora and Winters, 1987; Dornstetter and Verhulst, 1987; Maseng, 1986; Stjernvall and Uddenfeldt, 1987].

5.4.4 *Estimate of required spectrum*

5.4.4.1 *Parameter assumptions*

In this section we will introduce some values for parameters relevant for spectrum estimation (cell area, cluster size and duplex channel bandwidth).

It should be noted that, although the calculations assume that mobile stations and personal stations are accessing different cells of the network; it may be envisaged that they can access the same cells, for example if interface R1 = R2, or by use of dual-mode mobile/personal stations.

a) Voice services

i) Mobile stations (R1 interface)

Two future possible solutions are considered in order to give a range of estimates depending on the availability of certain techniques. In both cases, the distance between base station sites is taken as 1.75 km.

A conservative estimation can be based on the example of a system with a speech codec of 7 kbit/s with a duplex bandwidth of 25 kHz per voice channel associated with a cluster size of 9 (a cellular arrangement of 3 sites with 3x120°-sectors per cluster). This cellular arrangement, combined with a site separation of 1.75 km, leads to a cell area of 0.94 $km^2$.

A more optimistic estimation can be based on the example of a system with a 4 kbit/s speech codec and a duplex bandwidth of 10 kHz per voice channel; associated with a cluster size of 24 (a cellular arrangement of 4 sites with 6x60°-sectors per cluster). This cellular arrangement, again combined with a site separation of 1.75 km, leads to a cell area of 0.47 $km^2$. This implies the availability of speech codecs of approximately 4 kbit/s with the same resistance to errors as present ones and of equivalent quality.

ii) Personal stations outdoor (R2 interface)

The personal stations outdoor are assumed to be served by microcells at street level with one base station per intersection spaced at 125 m. Each cell covers 250 m of street length. This corresponds to a cell area of 0.016 $km^2$.

Due to the severe limitations on cost and power consumption for personal stations, a higher bandwidth of 50 kHz per duplex voice channel is assumed.

The cluster size of n = 16 for personal stations outdoor assumes a structure of 4x4 cells.

iii) Indoor personal stations (R2 interface)

The same bandwidth per voice channel of 50 kHz as for other personal stations is assumed. The cluster size of n = 21 is used, corresponding to a cluster size of 7 per floor repeated every 3rd floor [Porter, 1985].

The indoor personal stations are assumed to be served by indoor base stations each covering adjacent rooms along a corridor. An indoor cell size of 40 x 15 m equal to 600 $m^2$ is assumed.

b) Non-voice services

This section will discuss the required duplex bandwidth for data channels and derive, from the figures of 5.3.3 estimations of traffic needs in terms of equivalent 25 kHz duplex channels.

i) Duplex bandwidth considerations

- fast-fading channels (macro cells)

In this case, a powerful forward error correction (FEC) technique is needed to achieve high quality. It was assumed, taking into account future systems, that a 50 kHz duplex channel could support a 2.4 kbit/s user data with a BER of $10^{-6}$ and 9.6 kbit/s user data with a BER of $10^{-3}$.

- slow-fading channel (micro cells)

In this case it is assumed that a 50 kHz duplex channel can convey 16 kbit/s user data with high quality (BER of $10^{-6}$). However, error correction coding is needed to achieve this level of quality.

ii) Mobile stations

The telefax traffic is assumed to be carried at 4.8 kbit/s and therefore requires 100 kHz duplex channels. (4 equivalent 25 kHz duplex channels). Therefore the traffic (see 5.3.3) accounts for 180 equivalent 25 kHz channels/km$^2$.

The interactive data traffic is assumed to be carried at 4.8 kbit/s rate (2 equivalent 25 kHz channels) with an ARQ protocol. The total traffic (see 5.3.3) for this application is therefore equal to 74 equivalent 25 kHz channels/km$^2$.

The total amount (254 equivalent 25 kHz channels/km$^2$) for non-voice services is therefore estimated as 50% of the number of 25 kHz channels (or 100% of the number of the 10 kHz channels) needed for voice.

iii) Personal stations

The transmission in these cases is carried on 50 kHz bandwidth channels (same assumption as for voice). The traffic in 5.3.3 can be directly compared to voice traffic.

5.4.4.2 *Presentation of results*

Using the traffic and services assumptions of 5.3.2, 5.3.3, and 5.4.4 the estimate of required spectrum bandwidth is presented in Table IV for voice services, and Table V for non-voice services.

For voice services, the total required bandwidth ranges from approximately 160 MHz (scenario 1) down to approximately 110 MHz (scenario 2) according to future possible technical solutions presented in 5.4.4.

For non-voice services the total required bandwidth amounts to 65 MHz. In this case the two scenarios lead to the same result, since the duplex channel bandwidth for non-voice services is the same in both scenarios and the increased cluster size in scenario 2 is assumed to be compensated by higher C/I and resultant higher data transmission efficiency. The total bandwidth therefore ranges from approximately 230 MHz (conservative projection of future technology), down to approximately 180 MHz (optimistic projection of future technology).

In a number of countries an allocation of 50 MHz of spectrum below 1 GHz is used for existing cellular mobile systems, which are presently less spectrally efficient than FPLMTS scenario 2. If these existing systems remain in service, the traffic they carry should be subtracted from the FPLMTS traffic assumptions. The additional required bandwidth can then be estimated. The need for new spectrum (likely to be above 1 GHz) ranges therefore from approximately 180 MHz (scenario 1) down to approximately 130 MHz (scenario 2).

More detailed calculations must take into account specific technologies employed by existing systems. For example, if a technology comparable to scenario 1 was used by an existing system below 1 GHz and the technology of scenario 2 was used by FPLMTS, the overall additional needed bandwidth would be approximately 150 MHz.

It must also be noted that the estimation has been conducted taking into account dense metropolitan areas. Outside those areas the spectrum need is less and frequency sharing with fixed services should be considered.

The spectrum requirement for the paging service in FPLMTS has not been estimated since it is considered insignificant, compared with the spectrum requirements of other services in FPLMTS.

The spectrum requirements for the Land Mobile Satellite Service have not been included. This is considered relative to Decision 81.

## Table IV
## Spectrum estimation for voice services
## (example of scenario as described in 5.3.2 and 5.4.4.1a)

| | MS (interface R1) | | PS Outdoor (Interface R2) | PS Indoor (Interface R2) |
|---|---|---|---|---|
| | scenario 1 | scenario 2 | | |
| Radio Coverage (%) | 90 | 90 | >90 | 99 |
| E (E/km$^2$) | 500 | 500 | 1500 | 20000 (1) |
| a (km$^2$) | 0.94 | 0.47 | 0.016 | 0.0006 |
| $P_b$ (%) | 2 | 2 | 1 | 0.5 |
| n | 9 | 24 | 16 | 21 |
| b (kHz) | 25 | 10 | 50 | 50 |
| Traffic per cell (E) | 470 | 235 | 24 | 12 |
| Number of channels per cell | 493 | 249 | 34 | 23 |
| BW (MHz) | 111 | 60 | 27 | 24 |

E: Traffic density
a: Cell area
$P_b$: Blocking probability
n: Cluster size
b: Duplex bandwidth per channel
BW: Bandwidth
(1) Note: per floor

scenario 1: Conservative projection of future technology
scenario 2: Optimistic projection of future technology

## Table V
## Spectrum estimation for non-voice services
## (example of scenario as described in 5.3.2 and 5.4.4.1b)

| | MS (interface R1) | | PS outdoor (interface R2) | | PS indoor (interface R2) | |
|---|---|---|---|---|---|---|
| | Circuit switched | Packet switched | Circuit switched | Packet switched | Circuit switched | Packet switched |
| Traffic density (E/km$^2$) | 45 | 37 | insignificant | 150 | 2500 (1) | 2500 (1) |
| Duplex bandwidth per channel (kHz) | 100 | 50 | 50 | 50 | 50 | 50 |
| Bandwidth (BW) (MHz) | 56 | | 3 | | 6 | |

(1) Note: per floor

## 5.5 *Factors for choice of frequency band(s)*

### 5.5.1 *Propagation characteristics*

Various factors affect the propagation characteristics. They can be summarized in Table VI and as follows:

#### 5.5.1.1 *Outdoor propagation*

For outdoor propagation the law for decrease of the power as a function of propagation is around $r^{-3}$ to $r^{-5}$ for large cells and $r^{-2}$ to $r^{-6}$ for small cells. As frequency increases, fading rates and Doppler spread of the signal increase. There are limitations to the bandwidth of the transmissions resulting from these effects. The multipath propagation characteristics introduce a delay spread in the transmission which limits the achievable transmission rate.

The above effects also limit the coverage area. As the operating frequency is increased, received power is decreased due to increased path attenuation and reduced antenna aperture. Some experimental data with 20 m base station antenna heights indicate that this decrease is about 4 dB between 100 MHz and 10 GHz. Other data indicate a decrease of 6 dB between 900 MHz and 1.5 GHz, and 5 dB between 1.5 GHz and 2.2 GHz for antenna heights of 30 m in reasonable agreement with Report 567-3.

#### 5.5.1.2 *Indoor propagation*

Propagation measurements at 900 and 1700 MHz show that frequencies in this range are suitable for low-power indoor communications. An increase in frequency from 900 to 1700 MHz results in 5 dB increased loss due to reduction in antenna aperture. Penetration loss through walls and floors is greater at the higher frequency by about 3 to 6 dB depending upon the building's construction, which may affect favourably the frequency reuse in a multi-storey building. When the effects of floor and substantial walls have been removed, signal strength decreases at the same rate at both 900 MHz and 1700 MHz. For a mean effective radiated power (e.r.p.) of 5 to 10 mW the typical range, at 1700 MHz, for satisfactory speech communication will vary from 10m through two floors to 100 m on the same floor. The exact communication range depends on the nature of the building and the precise location of the transmitting and receiving antennas.

Overall propagation factors indicate that the use of a band below 3 GHz would be suitable.

**Table VI**
**Propagation characteristics around 1 GHz**

APPROXIMATE VALUES
(Available data as of 1988)

| | Outdoors | | Indoors |
|---|---|---|---|
| | 100m Antenna height (Large cell) | 10m Antenna height (Small cell) | |
| DELAY SPREAD | | | |
| -Median | 3 microsec | 0.15 microsec | 0.15 microsec |
| -Typical max. | 16 microsec* | 0.5 microsec | 0.3 microsec |
| PROPAGATION PATH LOSS | | | |
| Small Scale | | | |
| - Statistics | Rayleigh | Rician/Rayleigh* | Rician/Rayleigh* |
| - Coherence distance | wavelength/4 | wavelength/4 | wavelength/4 |
| - Cross-polarization | | | |
| *Coupling | information | 0-6 dB | 0-6 dB |
| *Correlation | not available | 0 | 0 |
| Large Scale | | | |
| - Statistics | LOG - NORMAL | LOG - NORMAL | LOG - NORMAL |
| - Power law | $r^{-3}$ to $r^{5}$ | $r^{-2}$ to $r^{6}$ | $r^{-2}$ to $r^{6}$ |
| - Std. Dev | 6-8 dB | 10 dB | 10 dB |
| - Coherence distance | 30 m* | 10 m* | 3 m* |

* DEPENDING ON SPECIFIC ENVIRONMENT

### 5.5.2 *RF technology*

The cost and power efficiency of the RF technology available to implement FPLMTS hardware are both adversely affected as the frequency band of operation is increased. The resulting consequences on battery operating durations for portable and personal stations and on cell structure must be considered when choosing frequency bands. It is not currently clear what frequency limit there will be for integrated circuit technology, in order to yield adequate performance in high volumes and low cost, in the late 1990s.

While it is desirable to have spectrum to meet demand cost-effectively, a fundamental technical constraint to its usability may be frequency agility of equipment. It is therefore advantageous to minimize the required frequency agility; moreover, it is generally accepted that the greater it is, the more expensive the equipment.

### 5.5.3 *Technical and functional compatibility/commonality*

#### 5.5.3.1 *General*

Frequency commonality should allow for the desired level of operational compatibility on the system(s). In principle, a complete commonality of one frequency band on a worldwide basis is desirable, but reasonable commonality can also be obtained through a common signalling band and sufficient overlap of the traffic bands to ensure compatibility.

#### 5.5.3.2 *Mobile station (Interface R1)*

Compatibility of an MS with different national or regional FPLMTS networks implies that the frequency bands of the MS should be at least partially overlapping with the frequency bands in which the FPLMTS networks are operating. Internationally agreed frequency bands also facilitate the planning of national networks and reduce the risk of harmful interference with other radio services. To determine suitable frequency bands for inter-regional mobility it is necessary to consider whether the allocation in a given ITU Region is primary or secondary and to consider geographic sharing.

#### 5.5.3.3 *Personal station (Interface R2)*

Frequency bands separate from the band used by mobile stations in FPLMTS may be envisaged, although sharing with other radio services might be possible. One continuous common band on a worldwide basis would be desirable, but reasonable commonality could be obtained through a common signalling band and sufficient overlap of the traffic bands to ensure compatibility of low-power microcell PS with different national or regional FPLMTS networks. This would minimize the required frequency agility and could reduce RF equipment cost, which is an important factor for the realization of an affordable universal personal station.

To accommodate different cell sizes for indoor and outdoor applications the frequency bands allocated to FPLMTS could be divided into a number of adjacent sub-bands. Indoor and outdoor cells in the same area could use adjacent sub-bands in order to deal with the case in which an outdoor cell blocks channels in many adjacent indoor cells.

5.5.3.4 *Mobile earth station (Interface R3)*

Mobile users operating over wide areas would benefit by having direct access to both mobile satellite and terrestrial systems. This could be most readily achieved by the use of adjacent satellite and terrestrial mobile bands.

Given the prospect of more than one mobile satellite system, it is desirable that technical and/or functional compatibility of mobile earth stations be a goal of the FPLMTS, so that mobile users are able to roam regionally and/or worldwide with the same piece of equipment.

It is noted that WARC-MOB-87 Resolution No. 44 urges administrations to encourage the development and manufacture of compatible user equipment in the mobile-satellite service.

5.6 *Radio frequency radiation hazard considerations*

Research to date has suggested, in general, that vehicular mobile radios do not cause radio frequency exposures in excess of currently accepted safety guidelines when factors such as intermittency of transmission and antenna location with shielding afforded by the metal body of a vehicle are taken into account. However, frequency-related power absorption studies in test-animals and models of man with a constant power density of 1 mW/cm$^2$ indicate that, in general, average specific absorbed power increases by a factor of approximately 100 for every increase in frequency by a factor of 10 in the range 1 MHz to 400 MHz.

These results suggest that there may be a range of combinations of frequency bands used and power density required which places limits on the safe operation of FPLMTS equipment. As frequency is increased, adverse propagation effects would require a compensating increase in FPLMTS radio power levels so that equivalent cell coverage can be maintained.

Question 52/1 of Study Group 1 requests the study of methods of predicting field strengths in the presence of transmitters for the purpose of allowing the assessment of radiation hazards by competent authorities (see Report 671). It is noted the IEC technical committee 12 has activities in this area [WHO, 1981; ANSI, 1982; IRPA, 1984; NCRP, 1984].

5.7 *Conclusions of frequency considerations*

5.7.1 *Evolution of traffic characteristics*

The current studies have identified the potential needs of the users for mobile telecommunications, in particular public mobile telecommunications.

These potential needs point to new categories of service and additional traffic, with voice and data being regarded as of similar importance in the future. A new category of service is appearing which requires low power microcells and generates estimated amounts of traffic in the order of thousands of Erlangs per $km^2$. However, this category of traffic is not the most spectrum demanding due to the intensive frequency reuse. The consequence is that there is likely to be an increased demand for spectrum usage in the field of public mobile communications.

5.7.2 *Consideration of spectrum needs*

Consideration of spectrum needs in the mobile field shows that the designation of frequency spectrum should take into account different factors.

Use of a frequency band between 1 GHz and 3 GHz is consistent with propagation and RF technology factors.

The concept of regional and/or worldwide roaming is an integral part of FPLMTS. Therefore the inclusion, at least partly, of a worldwide common frequency band would appear to be the first choice to enable universal access, particularly for personal stations.

Regional and national differences can be recognized in order to meet the varying magnitude of the demand for FPLMTS in different geographical areas. It will not be necessary to use the entire available spectrum in all locations.

It should also be noted that the equipment which would benefit from worldwide spectrum allocation, such as personal hand-held equipment, would likely have a limited range.

5.7.3 *Sharing possibilities*

The latter observations offer more possibilities for sharing with other services which are presently using the spectrum between 1 and 3 GHz. It should be noted that FPLMTS is to be an advanced system where control of the equipment will allow for adapting to various situations. In particular dynamic power control and frequency agility would aid conformance with planning criteria and should be further investigated. Frequency sharing or coexistence with other radio services may be studied in more detail by developing suitable algorithms and models.

5.7.4 *Timescales*

It is expected that existing mobile regional systems will likely be saturated around the end of the century.

The availability of systems with worldwide universal access is desirable. To this end it will likely be necessary that spectrum be designated for FPLMTS on a worldwide basis. This could be addressed at the next competent World Administrative Radio Conference.

Studies should be undertaken so that spectrum could become available and sharing criteria determined with a view to satisfying the potential evolving needs of FPLMTS around 1998 and beyond.

## 6. Compatibility and commonality

### 6.1 *Compatibility*

#### 6.1.1 *General*

Compatibility enables a service to be provided between equipment on both sides of an interface. These generic interfaces are described in 4.1.2 and shown in Fig. 3. See, in particular, interfaces 1, 3 and 8.

#### 6.1.2 *PSTN/ISDN - FPLMTS network and service compatibility*

Network compatibilty refers to all interfaces except 8 and 9 of Fig. 3.

Tables VII and VIII detail some points of service compatibility between FPLMTS and ISDN. They introduce the concept of mapping ISDN B and D channels onto FPLMTS I and C channels.

#### 6.1.3 *MS/PS, terminal and equipment compatibility*

This refers to interfaces 1, 8 and 9 of Fig. 3 and is mentioned in section 4.1.1.

##### 6.1.3.1 *FPLMTS - ISDN terminal compatibility*

Interface 8 in Fig. 3 recognizes that, in addition to terminals specifically designed for FPLMTS, ISDN user terminals or other CCITT standard terminals should be usable in FPLMTS (via appropriate adapters).

##### 6.1.3.2 *Radio interface compatibility*

Interface 1 of Fig. 3 refers to the generic radio link. Frequency allocation considerations, as they affect the generic radio link, are discussed in 5.5.3. Specific radio interface considerations are discussed in 4.3.

#### 6.1.4 *Billing and charging*

Similarly, a consistent structure for billing/charging is desirable for compatibility, but this may limit the flexibility of the system operator for innovative marketing.

### 6.1.5 *Further study*

In general, the detailed form of compatibility should be the subject of further study following a more precise definition of the services of FPLMTS.

The OSI layer model should be applied here in a form suitable for mobile communications.

## 6.2 *Commonality*

Commonality of technical elements of FPLMTS, for example, speech codecs, RF components, etc., enables cost benefits to be passed on to network operators and users. The specifications of FPLMTS have not as yet been defined in enough detail for meaningful comment on particular areas of desired commonality, but the attention of system designers is drawn to the benefits of this subject.

**Table VII**
**ISDN - FPLMTS Compatibility (General)**

| ISDN | FPLMTS (General) |
|---|---|
| Digital | Digital at interface between FPLMTS and ISDN network (as a minimum) (interface 2 of Section 4.1.2, Fig. 1). |
| Basic Access (integrated voice and data) made up of 2B + D where B = 64 kbit/s (Bearer channel) and D = 16 kbit/s (Signalling channel) | B Channel Functionality (flexible bit rate). For voice (at 2B + D baseband) 32 kbit/s, more likely 16 kbit/s or lower; based on spectrum and coding efficiency trade-offs. |
| Consider B and D channels as information content building blocks. | Compatible with ISDN D channel standards. D channel functionality may be spread over a number of radio channels depending on the multiple access techniques used. |
| | For FPLMTS, I (Information) and C (Control) will be used in place of B (Bearer) and D (Signalling) respectively, to signify the above differences within otherwise similar structures. |
| Error performance (64 Kbit/s) is stated in CCITT Recommendation G.821. This will be acceptable for data transmission (therefore very acceptable for speech.) | Voice quality will be a function of the coding and channel bit error ratio. |
| | Source and channel coding may be optimized for speech. Acceptable error performance for data traffic on mobile radio channels is a subject for further study. |
| Bearer Services at 64 kbit/s can be used to support voice and data services. | Extension of this capability to the mobile station would require provision of up to 64 kbit/s through the FPLMTS. |
| | Information on true user data rates to and from ISDN would make the provision of compatibility between FPLMTS and ISDN more efficient in spectrum usage. |

## Table VIII
## ISDN - FPLMTS Compatibility (Specific)

| ISDN | FPLMTS (Specific) | |
|---|---|---|
| | Mobile Station/<br>Personal Station | Mobile PABX/<br>Mobile Concentrator |
| Basic Access (2B + D)<br>144 kbit/s | 2I + C, I + C, C to 2B + D<br>(Note 1) | |
| Primary Access<br>1536 kbit/s (23B + D)<br>or<br>1920 kbit/s (30B + D) | | mI + nC<br>(Note 2) |

Note 1: Full extent of ISDN Basic Access at 144 kbit/s (2B + D) could be provided by FPLMTS at the expense of reduced FPLMTS service availability due to the increased RF resource required to support such mobile use.

Note 2: The exact values for m and n are subject for further study

## 7. Further work

The form of Future Public Land Mobile Telecommunication Systems (FPLMTS) in accordance with Decision 69 has been investigated.

The present Report and Recommendation 687 should be regarded as the first step in a long process of refinement. Many topics require further investigation; those which have been specifically identified are as follows:

### 7.1 *Services*

- Service Access (Section 3.4)
- Mobility Services (Section 3.3, 3.5)
- Network services (Section 3.5.5)
    * Bearer service including data service (Section 3.5.5; 1 - 3)
    * Teleservices (Section 3.5.5.4)
    * Supplementary services (Section 3.5.5.5)
- Speech quality (Section 3.6)
- Security (Section 3.7)
- Quality of service (Section 3.8)

### 7.2 *System architecture*

- Degree of FPLMTS integration and the level of integration with PSTN/ISDN (Section 4.1)
- A user-network interface standard (Section 4.1.1)
- The evolution and implementation of personal communications within FPLMTS (Section 4.2)
- Radio Interface requirements (Section 4.3)
- Signalling protocol (Section 4.3.2)
    * Refinement of Telecommunications Service Definitions

* Identification of all necessary functionalities needed for the radio interface.

* Identification of information and message flows between the above mentioned functional entities and their peer entities.

- Compatibility or commonality between PTN service in FPLMTS and PSTN/ISDN (Section 3.4, 4.4)

7.3 *Frequency considerations*

- Traffic considerations (Section 5.3)
- Radio Propagation characteristics (Section 5.5.1)
- Sharing possibility (Section 5.7.3)
- Spectrum availability (Section 5.7.2)

7.4 *Compatibility and Commonality*

- Detailed form of compatibility (Section 6.1.5)
- Structure of Information (I) and Control (C) channels (Section 6.1.5)
- Specification of FPLMTS and commonality (Section 6.2)

7.5 *Others*

- Operations, administration and maintenance

In addition to these areas of further work there are the matters of liaison and close cooperation with CCITT Study Groups, IEC, etc. To this end, it is anticipated that a number of CCIR Study Group 8/CCITT joint expert working meetings will be necessary.

A separate Report 1155 has been prepared highlighting the needs and interests of developing countries.

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