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TITLE: LOCAL SUBSCRIBER LOOP BY RADIO

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1 Introduction

1.1 The market

The local loop market is twofold:

- a wire-equivalent market, in which radio is used to provide services similar to those offered by wire distribution: this is the local loop without mobility;
- a market of convergence between local loop and mobility, in which the role of mobile technologies is extended to the fixed services to provide a combination of local loop and mobility services. This is a first step towards personal communications. We shall call it the local loop with mobility.

The above segmentation has a bearing on technologies, standards, frequency bands and certain aspects of licensing. In both cases, the services provided, starting at the level of traditional telephony, will progressively move towards multimedia through staged increases in the bit rates offered. The low cost of radio applications and the speed with which they can be introduced represent a major competitive advantage.

1.2 Standards and technologies

The technologies selected must be sufficiently open to ensure that they may be fed by a variety of sources, and must use the spectrum efficiently without causing disturbance to other networks.

In the case of the fixed local loop, this calls for no more than abiding by the radio co-existence and interface standards (both for the network and for subscriber terminals). The radio interface may be an owner interface. For the local loop with mobility, the relevant mobile technologies (CT2, GSM, DECT, DCS 1800, PCS 1900, LAN radio and subsequently UMTS, IMT-2000) are described in system specifications.

NOTE - The standards to be used in Europe are those published by ETSI, whether they were developed by ETSI or proposed by other organizations. New satellite technologies with high bit rates in the medium term will have to be taken into consideration.

1.3 Licences

Transparent licence-granting procedures are recommended, including a public enquiry on any restrictions on the call for applicants, extensive dissemination of the call for applicants, publication of reasons for choice, and appeal options for applicants not selected. As different frequency bands using different technologies can be used to meet the demands of a given market segment, the procedures for all the bands must be concomitant.

The fixed local loop is a specific distribution technology for fixed networks open to the public. The corresponding calls for applicants must allow for any combination of radio or wire technology to be proposed.

In the case of the local loop with mobility, the provision of service to fixed points and mobiles must be authorized under the same licence. It is preferable to issue regional licences, which are more likely to attract local investors without the risk of "creaming" urban markets. Thus, competition may be expected over a greater area of the country. Operators should commit themselves to achieving a certain coverage rate within the area (local, regional or national) covered by their licences.

The number of operators must be limited on the basis of market capacity. A gradual increase in the number of operators may, if necessary, be achieved by regular calls for applicants. Frequencies should be assigned on the basis of the traffic expected on each network. Operators should *a posteriori* have to substantiate their efficient use of the spectrum assigned to them. Assignments will be made in line with the increase in traffic.

Calls for applicants must allow complete freedom in the choice of technologies and services. The assignable spectrum must allow for such choice within the regulatory framework.

The following general principles for frequency fees may be taken into account:

- use of frequencies must be on a fee-paying basis, with the fees being flexible according to use;
- fees must be paid by all users of the spectrum;
- the fees serve to finance not only administration of the spectrum but also a fund for its reorganization;
- the arrival of new entrants may be facilitated by provisionally lower fees.

1.4 Spectrum assignments and allocations

In general, the spectrum below 470 MHz should be reserved for applications other than the local loop, in particular professional radio, except in rural areas where sharing is possible. Local loops with and without mobility will use the mobile and fixed bands, respectively, as provided for in the ITU Radio Regulations. Maximum flexibility must be maintained when assignments are made, whether in respect of the successive waves of licence granting or of the increased spectrum allocated to operators as their traffic flow evolves.

Towards 2005, it seems likely that some 300 MHz will be required for mobility in Europe, including the local loop served by the corresponding networks. Allowing for allocations already effected, a further 60 MHz will have to be found. Fixed radio local loop applications will require around 100 MHz within the same time-frame.

In the case of shared frequencies (dynamic frequency allocation systems on the one hand, and spread-spectrum systems on the other, wherein a block of frequencies could be shared), it would probably be sufficient to have a code of good conduct and a referee with monitoring facilities at his disposal to guarantee equitable use of the resource by the various operators. The division between private use and public networks is usually established by the different conditions of use. Where such conditions are not established, a separation between the frequencies will be desirable.

2 Market forces

The purpose of this chapter is to outline, as a basis for reflection on spectrum management, **the various types of requirement** with regard to radio local loop; the outline is based in particular on the following five documents:

- Wireless Access Local Loop - ITU - Radiocommunication Bureau, 6/11/96
- Wireless Local Loop and the Network Operator - ETNO - Document drawn up by Tim Jevvitt and Parti Vepsäläinen
- ETNO Reflection document on the results of the DSI-Phase II (MRSG-95/119)
- Radio in the loop - ETSI-ETR 139 (November 1994)
- Mobile communications in urban areas - SEE one-day seminar (7 December 1996).

These documents serve to highlight the dichotomy between two options:

1) **A "telephonist" vision**, which sees radio as a fixed mode of access. Under this perspective, the operator's interest in a radio local loop is basically motivated by advantages over cable in terms of cost, installation speed and ease of adaptation to the geographical distribution of demand. However, two types of strategy emerge from such operational and economic data, depending on whether the telephone operator is already set up or is a new entrant.

   In the case of the telephone operator already set up, use of the radio loop will mainly be envisaged for network extensions, i.e. in response to the creation of new urban areas (new towns, business parks on the outskirts of towns, etc.) or to the need to strengthen the rural network. This amounts to a **strategy of equivalence**, in which the radio local loop is seen as an alternative to the traditional wired loop. Furthermore, in certain cases, the aim will also be to extend the range of services on offer towards bit rates which are higher, but not so high as to justify the introduction of optical fibre.

   For the new operator, which will have to compete with an incumbent operator already in possession of a robust wired infrastructure, it will be a **strategy of replacement**, in which the radio local loop will seek to take the place of wire.

   The cases of deployment in Europe described in ETSI's ETR 139 (see figures in section 4) reflect these two strategies well, for example:

   - coverage of a new residential area (strategy of equivalence),
   - new operator in a competitive environment (strategy of replacement).

2) **A "personal communications" vision**, giving greater importance to mobility and continuity of coverage and leading to a strategy of convergence aimed at ensuring a wide variety of services on the basis of a single call number. This is the strategy adopted by many new entrants, who see mobility as a key competitive factor.

The following data serve to illustrate the strategies of equivalence and replacement:

- 90% of local loops in Europe are less than 5 km long;
- the following differentials argue in favour of radio:
  - the cost of radio access does not (up to the limit of range) depend on distance or type of terrain,
  - radio network capacity can be adjusted to demand,
  - the radio network is less affected by the geographical distribution of subscribers,
  - installation is faster,
  - operating and maintenance costs can be up to 25% lower than those of the conventional local loop,
  - fixed access costs (wire and labour costs) show an upward trend, while radio equipment costs are on the decrease.

The following worldwide data relate to the strategy of convergence:

– telephone traffic in 1993: 4 000 billion minutes, of which 1.4% by radio;

– growth of radio 1993/1992: +47%; 1994/1993: +53%;
growth of fixed: +5%.

Convergence implies the handling of both types of mobility:

– terminal mobility, related to coverage;

– personal mobility, i.e. assignment of a single number, regardless of the physical terminal used.

This may lead to a distinction between:

– the radio-relay interface providing the link between a terminal and the infrastructure network;

– the infrastructure network which, among other things, manages the mobility.

Whereas CT2 and DECT are access standards defining solely the radio interface, GSM is a consistent body of standards covering the radio interface and the infrastructure.

– In the first case (access network), convergence raises the question of ONP as applied to mobility functions, and the particular case of ONP as applied to access to intelligent network management functions.

– In the second case (architectures such as GSM, which include mobility management functions), the question raised by convergence is that of interconnection between networks and the corresponding access charges - a question that is technically simpler and politically easier to handle. Both of the approaches discussed above, i.e. with or without mobility, imply diverging technological choices:
  - evolution towards mobility favours cellular architectures,
  - the requirement that services be comparable to copper wire services implies specific fixed systems that may even include broadband (2 Mbit/s) or higher.

In addition to the land-based technologies, two families of satellite network have appeared: a first generation (Iridium, Globalstar, etc.), providing a basic telephony and low-speed data transmission service, and a second generation intended to provide access possibilities up to and including single-channel video.

All these considerations (fixed radio access or mobility, strategy of replacement/equivalence or convergence) reflect the points of view of operators, i.e. of **service providers**. However, in today's fully liberalized competitive environment, it is **demand** which drives the market. The question therefore has to be reformulated in terms of requirements. On the basis of the two documents from ETSI and ITU, those requirements would appear to be as follows:

Services

Local loop technology	Voice	Low-speed data	High-speed data	Single-channel video	Multi-channel video
Fibre/coaxial	✓	✓	✓	✓	✓
Copper pair	✓	✓	✓	✓	
High-speed fixed radio access	✓	✓	✓	✓	
Fixed radio access	✓	✓	✓		
Mobile radio access	✓	✓			
First generation satellite access	✓	✓			
Second generation satellite access	✓	✓	✓	✓	

Of course, the extreme diversity of requirements cannot be reflected in such a simplified table. Furthermore, any such table is static, whereas the evolution of requirements will inevitably accelerate. Countless questions are raised, to which there are no credible answers today. Just for example: what impact will the spectacular development of Internet-type networks have on the demand for ISDN access? Nevertheless, it is striking that the table as it stands points to the existence of a **dividing line, based on bit rates, between fixed and mobile access**. This bears out, from a marketing standpoint, the conclusions based on the objectives and constraints of the operators.

3 Market segmentation

The combined application of the mobility criterion and the services provided criterion leads to the identification of two market segments:

3.1 Fixed access (no mobility)

The use of radio is **transparent for the subscriber**. There are three categories, depending on the bit rate:

– Distribution: voice, data up to 9 600 bauds, Group III facsimile;

– ISDN loop: around 100 kbit/s;

– High-speed radio access: around 1 Mbit/s or higher.

3.2 Mobility

Mobility is regarded by many potential investors as a key competitive advantage vis-à-vis a telephone operator with a dense, and in many cases largely amortized, infrastructure.

The radio technologies that are applicable to the mobiles that are available today and that will be available over the next few years do not allow for much in the way of differentiation of services (voice, data, etc.) or achievable bit rates. Segmentation is therefore based essentially on the **degree of mobility**:

– **local mobility**, i.e. restricted to the area covered by a base station or group of base stations;

– **extended mobility**, without restrictions, to all areas covered by the network.

The extended mobility criterion must be understood as a synonym for **degree of roaming**. It is an important criterion from the user's point of view. It is also an important criterion from the point of view of the design and implementation of networks, as it brings into play the complex functions of mobility management, as executed, for example, by GSM exchanges.

The handover criterion - i.e. that of maintaining continuity of a call at the boundary between two cells - is technically less critical, as it calls for decentralized functions that are simple to implement locally. Thus in the case of a CT2- or DECT-type radio-relay interface used as an access technique, handover can be ensured locally even if the radio network does not have HLR/VLR functions.

Cellular architectures, being of the "intelligent network" kind, are particularly well suited to the implementation of radio local loops providing full mobility, especially through the combination of macrocells and microcells. The technique in fact has the dual advantage:

– of dealing without distinction (from the user's point of view) with mobility either at the speed of a moving vehicle or at walking pace;

– of providing the flexibility required for covering very dense urban areas;

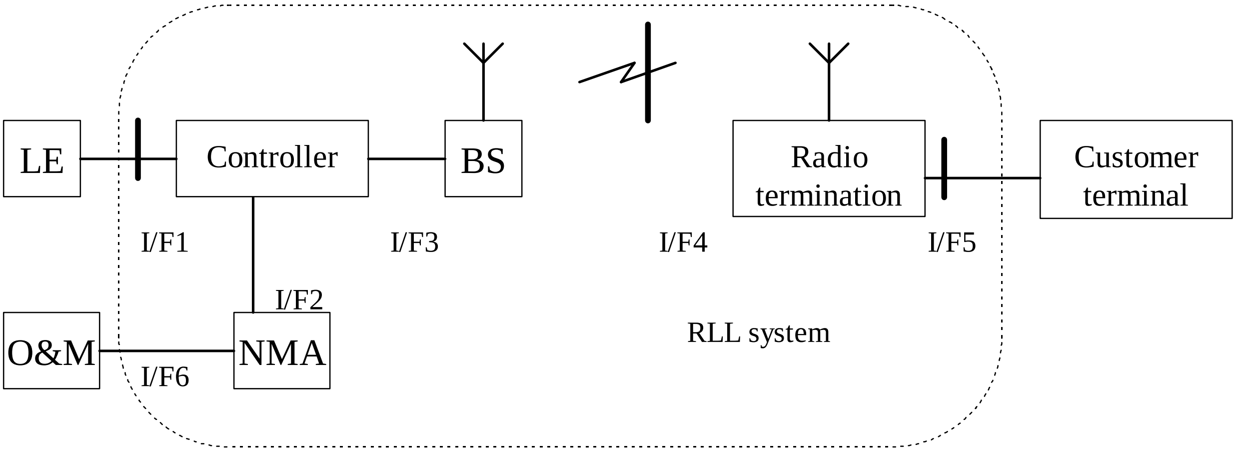
– of allowing bases outside or inside buildings to be associated, as the microcells do not have to be contiguous.

Furthermore, as shown by one of the presentations made to the SEE Seminar in June 1996, resource sharing between microcells and macrocells allows for an increase in traffic capacity. Finally, the standardized interface between the exchange (MSC) and base station controller (BSC) provides further freedom to operators as it enables them to integrate GSM, DCS-1800 or spread-spectrum base stations in a single network.

4 Examples of deployment

4.1 Example of deployment without mobility

The figure below (extracted from ETSI's ETR 139) describes the reference model used by ETSI. It should be borne in mind that these models disregard mobility.



ETR 139: November 1994

LE - Local Exchange
BS - Base Station
NMA -Network Management Agent

I/F1 - Local Exchange to Controller Interface
I/F2 - NMA to Base Station Interface
I/F3 - Controller to Base Station Interface
I/F4 - Air Interface
I/F5 - Radio Termination to Terminal Interface
I/F6 - Operational & Maintenance Interface

NOTE - There may be several BS and Radio Termination elements associated with a single system.

The four figures below illustrate the four typical examples of deployment drawn up by ETSI, namely:

- Example 1: Coverage of a new housing area (urban environment)
- Example 2: Rural area
- Example 3: Extension of a saturated network
- Example 4: New operator in a competitive environment.

The introduction of mobility in the network of a new operator merits particular consideration.

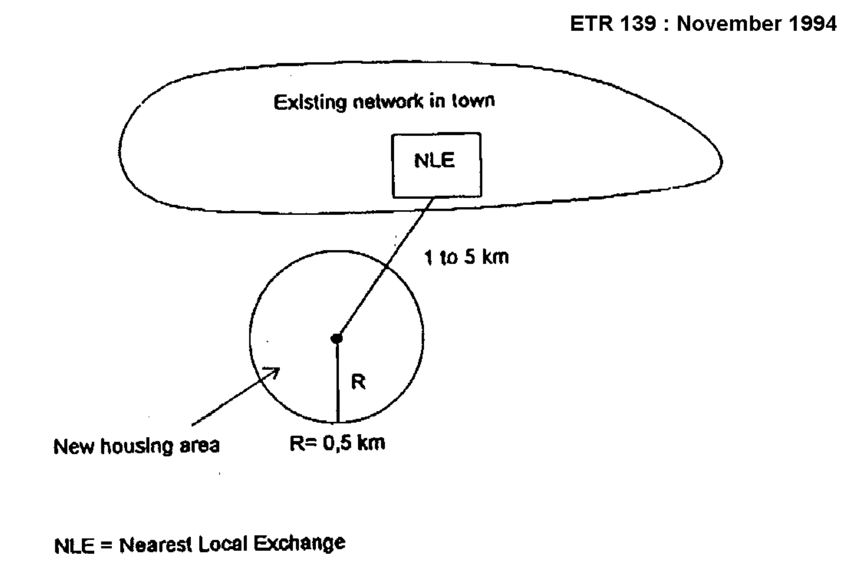


Figure 2 : New housing area near existing town

- Example 1: Coverage of a new housing area (urban environment)

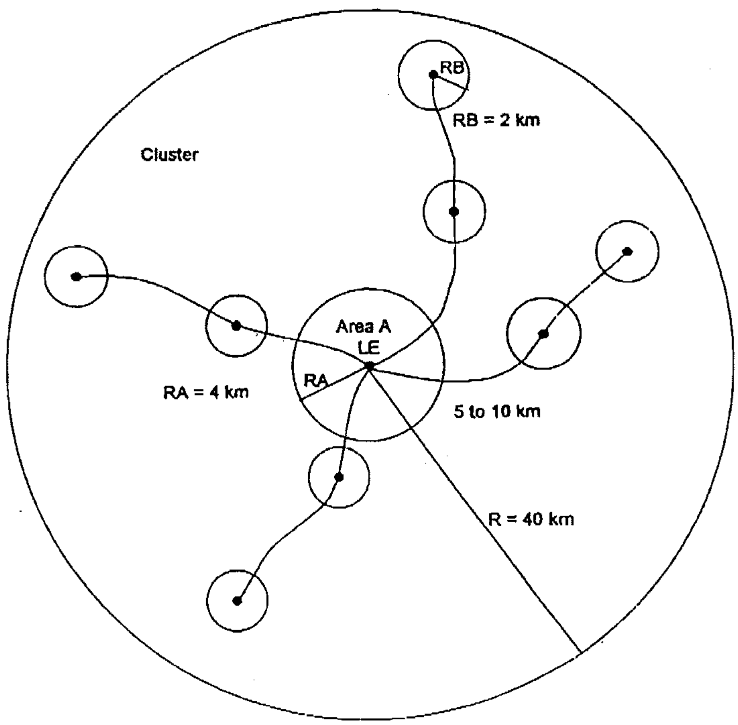


Figure 4 : A typical rural access network

- Example 2: Rural area

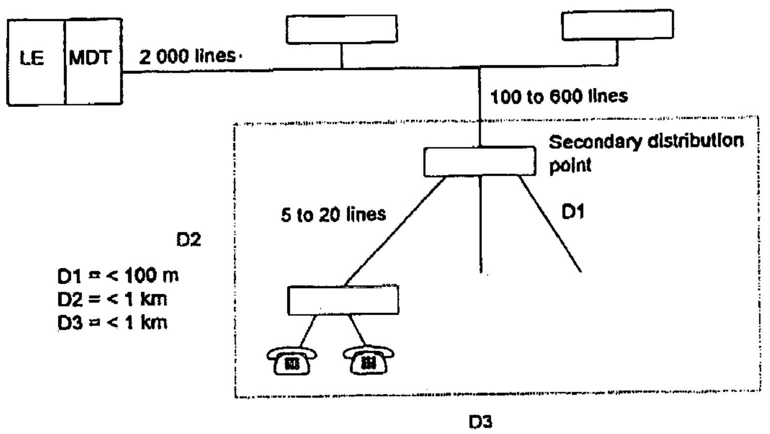


Figure 5 : The typical dimensions and line amounts of a segment

• Example 3: Extension of a saturated network

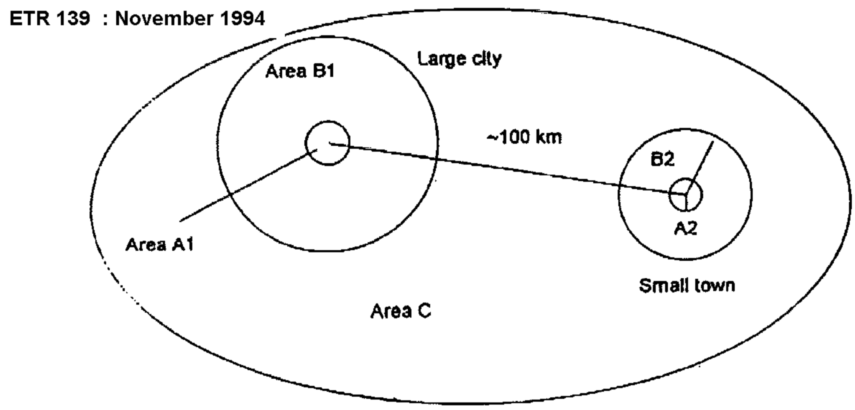


Figure 6 : The defined areas of deployment example 4

• Example 4: New operator in a competitive environment

4.2 Example of deployment with mobility

On the basis of an example of a radio local loop system initially designed for fixed subscribers, we shall begin by presenting the conditions to be satisfied for introducing mobility. We shall then consider the parameter of the surface of the mobility area.

4.2.1 Introduction of mobility

For purely strategic and economic reasons, the service for the subscriber may be deployed gradually, starting with a fixed service requiring fewer base stations to which remote subscribers may be linked up (using directional antennas), with subsequent diversification of the offer through the addition of mobility.

How, using a protocol suited to mobility management, can mobility be introduced in a network initially designed for fixed installations?

The mobility offered may initially be restricted to the subscriber's local area (some public networks will not cater for mobility in the subscriber's home, since mobility can be achieved very simply by using cordless terminals). Thus, when out on foot, the subscriber will be able not only to make calls but also to be reachable on his usual number as part of his basic subscription, extended by the operator by the means of a mobility option. This service can only be provided if the operator sets up additional base stations within the initial gridding, ensuring a satisfactory link quality even though the portable terminals have only low-gain omnidirectional antennas.

4.2.2 Extension of mobility

Mobility within a single cell of the area's coverage system is easy to manage since there is no need to search for the mobile terminal, which must by definition be in the base station's coverage area. When mobility is extended to several cells governed by a single switching centre, locating the mobile may be more complex than with a single cell, but can be effected by the switching station that manages the mobile subscribers attached to it. Such restricted mobility may nevertheless cover a fairly large area of several square kilometres (part of a city or a small town).

Beyond this, "extended" mobility requires proper mobile telecommunication networks providing regional or national coverage.

If the subscriber's fixed station is in fact a fixed mobile station, extended mobility is easy to achieve. The downside of this, however, is that the numbering will be specific to the mobile network and that transparency will be restricted on account of the voice coding implemented in the mobile network.

- A local service can also be added on to a mobile network: for example, DECT base stations can be linked to a GSM network.

5 Propagation and penetration constraints

It goes without saying that in any discussion of radio local loops, account must be taken of the physical constraints inherent to radio, especially when the purpose is to shed some light on the question of frequency allocations. The few studies that have been published confirm the extreme complexity of the subject and the considerable impact of such constraints on the cost of infrastructure and quality of service. None of the phenomena encountered can be ignored:

- reflection (facades, …)
- diffraction (roofs, corners of buildings, …)
- scatter (balconies, doors, street furniture, vegetation, …), with its numerous consequences:
  - multipaths, provoking frequency selectivity and therefore temporal dispersion
  - spatial variability of level, transformed by mobility into temporal variation, which can reach 20 dB over a distance of 1.5 metres.

Measurements effected by CENT (France) on St. Louis Island show that propagation time deviations could reach (at 900 MHz) 2µ (impulse response spread). Penetration into buildings also poses very serious problems:

- loss varies from 10 to 30 dB according to the mobile's position vis-à-vis the building facade;
- variations of 2 to 20 dB can occur, depending on the building material;
- classical macrocell penetration models show a gain per storey (1 to 2 dB) which has not been tested for microcells.

On the basis of these observations, two conclusions may be drawn:

a) Encouragement should be given to further propagation studies in the field, and above all to publication of their results;

b) Building interiors will very often be covered by locating public or private bases within them. This does nothing to change the fixed access/mobile access dichotomy, but it may have consequences:

   – on licence allocation conditions; and

   – on frequency requirements.

Finally, it should be noted that, whereas it may be acceptable when placing a call to have to move about inside a building to find a properly covered area (e.g. near a window), **the loss of an incoming call is unacceptable**.

Furthermore, the concept of "local mobility" (for example, roaming restricted to bases linked to the local exchange) seems to go down very badly with users. **The absence of handover between cells belonging to the same local area** likewise tends to be regarded by users as an unacceptable restriction.

6 Regulatory bases

A study of both markets and technologies leads to the conclusion that very different types of service, including radio local loop, and very diverse technologies, will have to coexist. It will only be possible to accommodate such diversity with **an open, structured and transparent regulatory policy**. This section therefore presents regulatory principles from which the frequency assignment policy to be addressed in the next section flows.

Regulation must allow the **diversity of services and technologies to develop freely** by authorizing both the extension of existing systems and experimentation with new ideas. To this end, users, manufacturers and operators must have **a long-term vision** of the conditions pertaining to their investments.

As mentioned in previous sections, anyone providing radio local loop services **must state explicitly whether mobility is possible or not**, since the rules will be different in each case. **However, it is undesirable to establish a link between applications and technologies**: the operator is free to choose its technology providing it can justify the results, especially with regard to the **spectrum efficiency** achieved. Technologies can indeed prove effective and/or economical for a very wide variety of applications depending on the context.

6.1 Radio local loop for fixed subscribers

Such systems have been in operation for over fifteen years using radio-relay frequency plans and serving mainly rural or isolated subscribers.

More recently, systems have also appeared for serving urban and suburban subscribers.

The development of such systems should take place within the framework of local or national operator licences authorizing both wire and radio approaches. Accordingly, licences for fixed radio networks should be granted on the same regulatory bases as licences for wired networks. On the other hand, networks which were initially intended for fixed subscribers but which could evolve with the introduction of mobility should be regulated in the same way as mobile services.

Frequencies should be allocated according to the general principles set out in section 7 below.

6.2 Existing mobile radio systems evolving towards local loop

We have seen that cellular and telepoint mobile radio technologies can satisfy this new market by providing the mobile dimension. **This evolution of mobile radio systems that either exist already or are currently being deployed must be facilitated**. It requires the allocation of more spectrum to such systems so as to maintain the quality of service provided.

In addition, a subscriber's use of a terminal at home on a permanent basis or the connection of public booths to mobile networks must be authorized.

6.3 Introduction of new technologies

Technologies especially suited to this new demand will not fail to come on offer, and will have to be compared with one another and with the options inherited from mobile radio systems. Such experimentation must be facilitated by a rapid licensing mechanism that is perfectly transparent and harmonized at the regional level, and which can have no adverse repercussions on future developments. Hence, licences assigned by geographical area and for bands restricted to the requirements of experimentation should be temporary and subject to an obligation to publish results.

Following the experimental period, the granting of commercial operating licences must be preceded by transparent calls for applicants, the results of which must be substantiated and open to appeal.

6.4 Standardized interfaces and open specifications

Opening up to competition **must not**, however, **lead to a fragmentation of the market**, which would undermine the sector's stability and distort costs: the full range of sources for all technologies selected must be assured, as must adequate production levels. The degree of standardization imposed must be suited to each situation.

Indeed, some systems **with little or no roaming** could be granted general licences to use certain bands on a shared and uncoordinated basis. Then the constraints imposed could **be limited to radio coexistence standards**, such as power, spectral purity, etc., without the imposition of detailed standards. In this case, the user interface alone could be standardized to enable subscriber terminals to be connected from different sources to the operator's fixed radio terminal.

For other systems, especially **mobile systems, more detailed compatibility standards** could be imposed.

Thus, for each case, a compromise must be found, which could include:

– definition of the main interfaces, especially the radio interface and network interfaces;

– definition of minimum services, for example basic telephony.

In all cases, accessibility to the specifications used must be insisted upon, thereby making for healthy competition between providers. Finally, it may be noted that, for broadband and multi-service applications, broadcasting systems such as MMDS, or satellite broadcasting systems such as SKYBRIDGE or TELEDESIC, will have a role to play in the future.

6.5 Restriction on the number of competing operators

The number of competing operators in a single geographical area must be controlled. A balance must be found (which may differ from one area to another) between, on the one hand, opening up to competition with consequent lower costs and, on the other, market fragmentation and the associated risk of inadequate volumes. The licence-granting mechanism must be fully transparent and include public consultations and an appeal procedure following selection. Licence-holders must be subject to **performance obligations**, and efficient use of the spectrum must be a criterion for granting or renewing licences or for band extension.

7 Frequencies for radio local loop

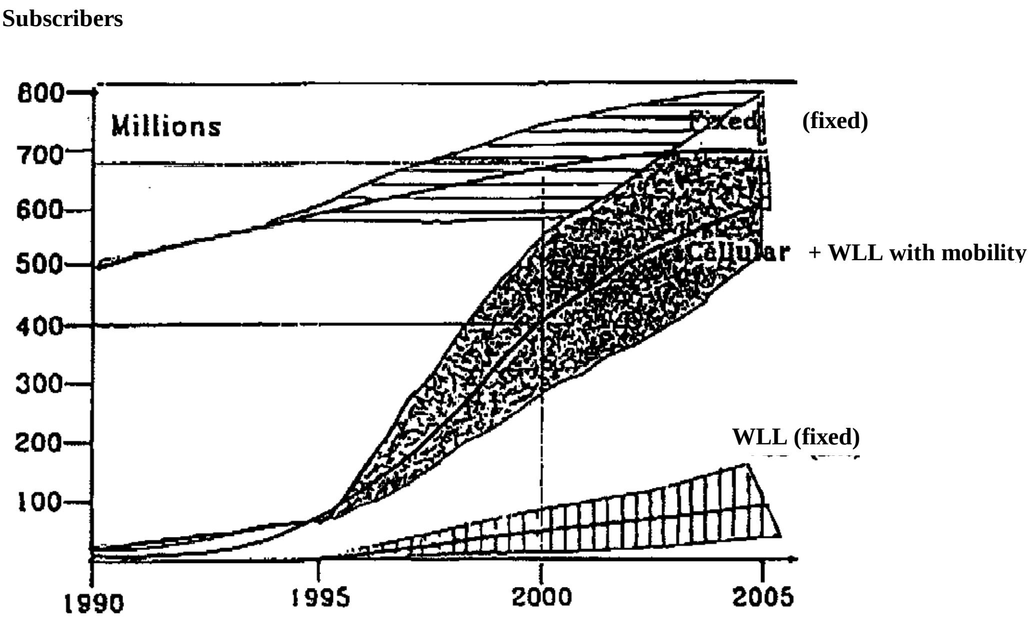
7.1 Overall estimation

An estimation of spectrum requirements on the basis of technologies and applications is not feasible, as the quantitative requirements depend on:

- the qualitative evolution of demand, particularly in terms of the number of minutes of conversation per telephone subscriber, the demand for high bit rates, etc.;
- the speed of overall market growth;
- the distribution among the various competing technologies.

That is why it is necessary to maintain as much flexibility as possible by issuing licences in successive waves and granting experimental licences in the context of dynamic spectrum management with regular reorganization.

The following graph, which is valid worldwide, is a basic model, and the margin of uncertainty it portrays is understandably large. However, it should be emphasized that the forecasts for growth in mobility have regularly had to be revised upward over the past ten years.



Evolution of number of subscribers 1990-2005/Source: Philips - CEPT Conference 1996

NOTE - In the case of France, the following quantitative assumptions may be made:

- The number of fixed main lines can be expected to rise from 32 million in 1996 to 40 million in 2005, with 2-3 million accounted for by radio.
- The number of mobile lines should exceed a penetration rate of 30% by 2005 (in 1996, Sweden and the United States attained rates of 30% and 17%, respectively).
- In the same year, the number of broadband radio lines (bit rate >1 Mbit/s) could reach several hundred thousand.

7.2 Band sharing

In the case of shared frequencies (dynamic frequency allocation systems on the one hand, and spread-spectrum systems on the other, wherein a block of frequencies could be shared), it would probably be sufficient to have a code of good conduct and a referee with monitoring facilities at his disposal to guarantee equitable use of the resource by the various operators.

The division between private use and public networks is usually established by the different conditions of use. Where such conditions are not established, a separation between frequencies will be desirable.

Specific measures will have to be taken to permit the introduction of one or more operators at intervals, so as to enable the new entrant(s) to set up a network which at the outset is likely to have a base station density that is lower than that of the competitor(s) already in place.

It will also be necessary to analyse cases liable to result in inefficient use of the spectrum: systems using different technologies, unsynchronized systems, different engineering systems that may produce cells of different sizes …