# 8

# Advanced DECT/PWT Applications

## 8.1 Introduction

The preceding chapters have covered the basic protocols in considerable detail, including their operation and standards. This chapter looks at some of DECT and PWT's more advanced applications and features, although not in much depth. The reader is referred to the application-specific standards and reports for more details. The documents are listed in their entirety in the bibliography.

These applications are covered here:

- Cordless PABXs;
- Interworking of cordless equipment with the ISDN;
- Data services;
- RLL applications, including repeaters;
- Interworking of cordless equipment with GSM-type networks;
- Roaming of cordless terminals across public and private networks.

Two other specific features essential to cordless systems (and particularly PABXs) also are discussed:

- System planning and deployment;
- The use of identities and addressing.

In the technical descriptions of the DECT and PWT systems and their standards, the base standards [1,2] are a menu of features and procedures covering all sorts of applications; for any specific application you need implement only a subset. For many applications, there are application-specific profiles, which are other standards describing which of the base standard's features are required. All profiles which support speech telephony, are based on the GAP [3] so that DECT handsets conforming to those profiles also are GAP compliant. If the application does not include speech service, the European regulatory regime does not require DECT systems to comply with any of the application-specific standards.

### 8.1.1 Basic Voice

For the support of all voice applications, as covered in detail earlier in this book, the essential subset of DECT features is the GAP in Europe [3] and the CPAP in the United States [4]. In Europe, all DECT systems that are capable of supporting the "3.1 kHz telephony" speech service must comply with the GAP. That means DECT handsets may be used to get speech service from any base station that offers it, regardless of its manufacturer. That is not a requirement in the United States, but the CPAP gives the opportunity to ensure interoperation.

Because of the 10-ms TDMA frame, digital streams such as speech cannot be delayed less than that in passing through a DECT or PWT system. In practice, another 1 to 2 ms also is incurred in any analog circuit that incorporates filtering, so the standards permit a total one-way speech delay of up to almost 14 ms. As a result, all fixed parts have to incorporate some echo control. The precise nature of the echo control is covered in the speech coding and transmission standard [5].

### 8.1.2 Cordless PABX

The cordless PABX probably is, after the residential telephone, the main application for which DECT and PWT originally were designed. It certainly drove the initial phases of protocol design, leading to fundamental choices in the PHL and the MAC layer, that give the system its characteristics, provide adequate flexibility, and ensure the capacity to support cordless offices of many thousands of users.

The cordless PABX changes one of the old but fundamental assumptions of a wired PABX that a dialed number corresponds to one (or more) fixed ports at its periphery. There are two ways of making that change. The first is to build into the PABX's software the new paradigm that a terminal may be connected to any "port" (i.e., attached to any radio base station) and that it may change ports at any time (even during an established call). The second way is to add an adjunct to a standard PABX that transparently routes calls from fixed ports to the appropriate radio cell. Both approaches are covered in Section 8.2.

Two key topics related to cordless PABXs and other multicell systems also are covered: system planning and deployment in Section 8.3 and system identities in Section 8.4.

### 8.1.3 ISDN Interworking

The connection of DECT and PWT systems to the digital public telephony network, the ISDN, is not in itself considered to be ISDN interworking, since the protocol is designed to be generic and not network specific. However, handsets are allowed to (1) access ISDN-specific services in such a way that the handset plus base station look like an ISDN terminal; or (2) carry an ISDN connection so that a normal ISDN terminal can be connected to a socket on the handset. Those two means of interworking with the ISDN are covered, respectively, by two different ISDN interworking profiles, which are described in more detail in Section 8.5:

- ISDN access profile (IAP) [6];
- ISDN intermediate profile (IIP) [7].

### 8.1.4 Data Services

The protocol creates bidirectional 32-kbps continuous circuits to carry coded speech. For creating simple data streams, that channel also can be used as an uncorrected data connection, or it can be used with error control to deliver data circuits with lower data rates (the DLC's LU5 and LU6 services). However, the base standards also support more versatile packet-mode communications that are used to build up a wide-ranging set of data capabilities. The generic data transfer capabilities in the base standards are brought together in the data service profiles, into capability sets that support specific applications and services. The profiles are labeled A to F and subdivided into class 1 (without mobility) and class 2 (with mobility) (Table 8.1). More details of these services are contained in Section 8.6.

**Table 8.1**
Summary of Data Service Profiles

| Profile | Classes | Applications |
|---|---|---|
| A/B | 1, 2 | A generic frame relay service. For example, to carry connectionless traffic up to 24 kbps (type A) or 552 kbps (type B), extending token ring and Ethernet LANs. Class 2 covers mobile applications, including direct interworking with the Internet. |
| C | 1, 2 | High-integrity generic data stream services built on the generic frame relay service of type A/B, including interworking at V.24 interfaces. |
| D | 1, 2 | Isochronous transparent transport of synchronous data streams for closed user groups (class 1) or for public and private roaming applications (class 2). |
| E | 2 | A roaming low-rate short message service (e.g., alphanumeric paging). Point-to-point and point-to-multipoint services are supported. |
| F | 2 | A mobile multimedia messaging service including e-mail, facsimile, short-message service (SMS), and world-wide web (WWW) access, including file transfer protocol (FTP) and hypertext transfer protocol (HTTP). |
| PPP | 2 | Support for Internet protocol (and other datagram types) over PPP, based on the A/B class 2 and C class 2 profiles. |

### 8.1.5 Radio Local Loop

One of the more important areas in the application of radio in the public telecommunications service is the replacement of the copper wires from a local telephone exchange into a home or other building. The rationale for doing that by radio is that the cost of installing and maintaining copper cables is very high, and although radio systems initially may be more expensive, they ultimately work out cheaper to install and maintain.

The protocol's flexibility in carrying many different telecommunications services makes it ideal as a relatively short-range radio replacement for the "local loop." It provides both traditional local-loop services and advanced features. In trials using high-gain antennas, ranges of up to 5 km have been achieved. In practice, in real environments with obstructing buildings and trees, for example, more modest ranges may be achieved on average.

The RLL access profile is divided into two parts:

- Part 1 covers basic services, including standard telephony, a 64-kbps bearer service, and the essential operations administration and maintenance procedures needed for an RLL.
- Part 2 adds ISDN and broadband packet data services.

Section 8.7 gives more details, and Section 8.8 gives details of the wireless relay stations that allow all the protocol's services, including RLL, to be extended in range where obstructions or other problems prevent direct service from being provided from a base station.

### 8.1.6 DECT/GSM Interworking

DECT and PWT basically are radio access technologies that do not specify any network mobility functions. However, they do specify support for mobility functions existing outside the cordless air interface. That makes DECT or PWT an ideal partner for a digital cellular technology, such as GSM, that already specifies how to handle mobility within its network. In fact, there are not always perfect matches between the models that the cordless system has for things such as mobility, identities, and security, so the partnership between the cordless access technology and the cellular mobility infrastructure is not always ideal. Nevertheless, there are two different ways to make the necessary adaptations to allow cordless systems to be connected to GSM900, DCS1800, or PCS1900 infrastructure: (1) connect cordless fixed parts to the A-interfaces of a GSM network or (2) connect complete cordless PBXs to GSM infrastructure through the ISDN using the DSS1+ protocol [8]. Both mechanisms have application profiles that allow GSM's mobility and other functions to be made available to cordless handsets. Users then can have the same services through their cordless handsets when they are out of range of their GSM system.

There is also a third means for cordless and cellular systems to interwork: having a dual-mode cordless and cellular handset. That does not require the interworking of fixed systems, and the handset just selects the appropriate operating mode for its environment, for example, DECT when it can see a DECT system and GSM otherwise. More complex and useful arrangements also are available. The interworking of cordless and cellular systems is covered in more detail in Section 8.9.

### 8.1.7 Public/Private Network Cordless Terminal Mobility

Cordless terminal mobility (CTM) is described in DECT's CTM Access Profile (CAP), which details how to allow users of cordless terminals to roam between multiple interconnected cordless networks and receive their telephone service. It applies whether the relevant networks are public or private. The CAP provides the means by which any cordless network can communicate with another to allow it to serve handsets that have their homes on other networks.

The ability to roam between networks also may be provided by interconnecting the cordless networks via the GSM network (using the DECT/GSM interworking profile). The CAP provides alternative mobility functions through the ISDN. Section 8.10 gives more details.

## 8.2 Cordless PABX

Strictly speaking, the DECT and PWT standards have nothing to say about either cordless PABXs or their private networking. They are telecommunications access protocols. However, built into the cordless protocol are the support mechanisms for cordless PABXs and the means to support most types of communications network, including private (or enterprise) networks. Where voice is carried by a DECT PABX, it can be assumed that any unrecognized handset is GAP compliant. If it is not, then interoperation cannot be guaranteed. If data service is provided, one or more of the data profiles, according to the service, also may be supported (covered in Section 8.6).

### 8.2.1 What is a Cordless PABX?

If you take a normal PABX and attach a lot of normal DECT or PWT cordless telephones to a number of the ports, do you have a cordless PABX? No, of course not. What you have is a limited form of mobility for the users, centered on the fixed sockets into which they normally would plug a wired telephone. What you effectively get is an extension of the telephone cord between the handset and the base station. That in itself may be a useful step forward, but it is not a cordless PABX.

The cordless PABX goes further. The ideal cordless PABX effectively replicates the fixed socket you use for your normal telephone *everywhere* within its radio coverage area. That requires a shift of emphasis in the central switch serving the cordless users. Normally a dialed number is translated by the switch's central processor to a fixed location. In that sense, the location of a numbered port is at the periphery of the switch. An incoming call is routed to the port corresponding to the dialed number. But now the periphery of the switch is connected to a group of cordless base stations instead, and there is no longer any correspondence between the port through which an incoming call must be switched and the number dialed for the telephone call.

That means that the cordless PABX has to maintain a database that connects a dialed number to a particular portable set rather than a fixed port, and a second database that records at which location that set is to be found. Sometimes the second database can be imprecise. In the DECT/PWT system, a call to a handset is put out over at least one cluster, which may comprise as many as 255 radio cells; and the handset is responsible for maintaining knowledge at all times about the best cell to contact within the cluster whenever it hears the broadcast information notifying it of an incoming call. That is one of the main mobility design features of the protocol. By decentralizing some of the mobility management to the handsets, the mobility management in the central cordless switch is greatly simplified for even very large systems.

Supporting both mobile and nonmobile terminals is easy. Fixed telephone sets just are treated as mobile handsets that never move.

### 8.2.2 Differences Between a Cordless PABX and a Wired PABX

It may seem obvious, but a cordless PABX has to be sold in a very different way than a wired PABX. The reason is that the first and most important service it provides is radio coverage. By the time customers have successfully operated their very first handsets, they will have had to install and pay for all the base stations needed to provide radio coverage. Each radio base station will have cost substantially as much as a reasonably featured business telephone set, so the cost per line of the first few handsets will seem enormous.

Yet telephone system buyers—and their senior management—probably will be used to dimensioning telephone system purchases by the number of users rather than the area of the premises, and they will be used to buying their switching systems at a certain cost per line. So selling mobility in the workplace is very different from selling a normal fixed PABX, and the potential difficulties in selling the advantages of in-building mobility and changing the outlook of telephone service buyers should not be underestimated.

### 8.2.3 Integrated Support Versus Adjunct Support

Changing one of the basic switch paradigms from "one dialed number corresponds to one physical port" to "one dialed number corresponds to one handset anywhere in the radio coverage area" usually means a fundamental change in a PABX's core switching software. Making that change can be done in one of two ways. The first way is to bite the bullet and make the changes in the core software; the second is to connect a special-purpose cordless switch to the main PABX as an adjunct, and allow the adjunct to translate from one paradigm to the other. If you are providing mobility for a large PABX, it may be far easier to connect an adjunct mobility processor to the switch rather than update the core software to add mobility support.

The normal way to design an adjunct is to realize that the normal telephone services you are getting should come from the core switch. The adjunct should just add mobility. The adjunct should then be programmed, in combination with the portable, to pass through any request for special features from the portable and any responses in the opposite direction.

### 8.2.4 Nonconcentrating Adjunct Versus Concentrating

There are perhaps two main types of cordless PABX system you could design: a concentrating system or a nonconcentrating system. Fully integrated cordless support within a PABX normally will be of the concentrating variety, whereas an adjunct reasonably may be of either type. We illustrate the difference here by referring to adjunct support for cordless mobility (Figure 8.1).

The key to the nonconcentrating adjunct is that the number of handsets is equal to the number of trunks ($Nh = Nt$). The adjunct simply associates one handset with one trunk. Hence, an incoming call indication on one trunk tells the adjunct which handset to call. The number of cells is not related to the number of trunks or handsets but rather to the coverage area required.

In this sort of system, a handset may be twinned with a fixed phone, so it will ring at the same time. In that way, it is possible to introduce a mobility service in parallel with an existing fixed system. The features of the fixed system are available via the existing fixed phones, and users have the ability to receive and originate calls when away from their normal place of work.

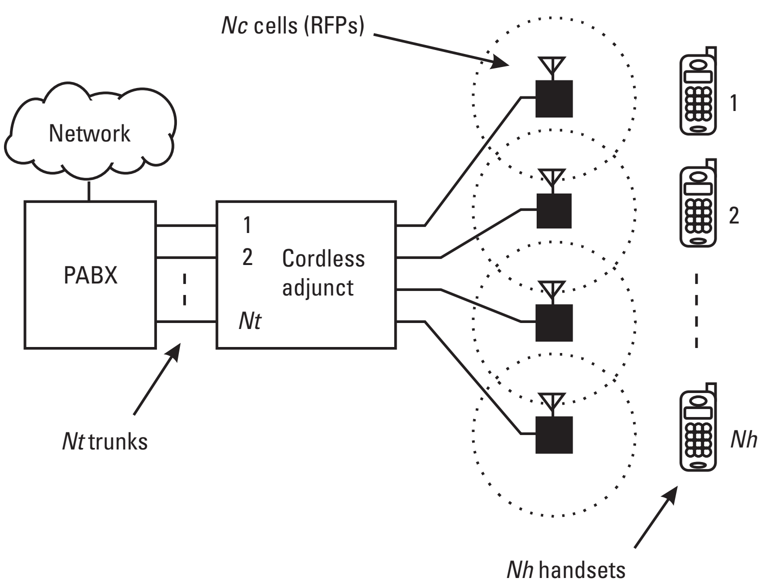


**Figure 8.1** Adjunct support for cordless mobility in a PABX.

This sort of behavior is possible even with analog trunks between the adjunct and the PABX. Simply detecting the ringing voltage on the trunk is enough for the adjunct to initiate a call to a DECT or PWT handset. That way, a cordless adjunct can connect to any PABX with analog extensions, regardless of who manufactures either the PABX or the adjunct.

There are some disadvantages. With analog interconnect, the ringing voltage will be cadenced, with gaps between the ringing voltage pulses. The adjunct has to implement a timeout long enough to cover the gaps and must continue to cause the handset to ring across those gaps. When the incoming ringing stops, it may be some time before the handset stops indicating an incoming call. That may cause a handset user to answer a call attempt that has just ceased. Also, where the adjunct provides for a cordless handset to act as an additional instrument in parallel, the handset may continue to ring for a short period after a fixed extension has been answered.

In a nonconcentrating adjunct, special features seen by the user usually are those of the PABX rather than the adjunct. The features of the fixed PABX are made available via the portable phone if they can be accessed via special sequences of the normal keys 0 to 9, *, and #. The keys may be dialed by the handset user directly or be assigned within the adjunct to special key functions on the handset and translated in the adjunct itself. The nonconcentrating adjunct usually also provides no internal switching. That is left to the main PABX, and all calls are passed to the main switch even if they are between cordless handsets supported by the adjunct.

In the concentrating adjunct, there are fewer incoming trunks than handsets ($Nt < Nh$). In that case, an incoming call must be accompanied by a signal that indicates which of the handsets it is for so the adjunct can make the appropriate connection. Communication of that type is largely the province of digital trunks and is usually an area where the digital trunking is proprietary to the PABX. In that case, the adjunct may well not be a general-purpose adjunct and may be specially designed to work with a specific switch.

## 8.3 System Planning and Deployment

The first thing to say about the planning and deployment of a multicell public DECT or PWT system (or any cordless PABX) may not appear to be directly related to planning but rather to the marketing of the system. It bears repeating that you need to sell a customer radio coverage before you even sell the first terminal. That principle is the key to the deployment of a cordless system as well. You first must plan the coverage area of a system before you even consider the numbers of users and terminals the system will support.

Planning and deployment as we describe them here do not really apply to single-cell systems, only perhaps the capacity calculations. This treatment therefore mostly applies to multicell systems, such as PABXs and public access systems.

### 8.3.1 Radio Coverage

DECT and PWT systems may seem like cellular radio systems in miniature. They are indeed similar. However, unlike normal cellular radio systems, the great thing about the protocol's internal dynamic channel allocation function is that you never need to be concerned about allocating frequencies to cells. Provided your equipment follows the rules for channel selection within the standard and is not overloaded with users, the protocol will take care of all aspects of frequency planning.

The placement of cells to provide coverage is not an exact science. Inside buildings, it is even worse than outdoors. The type of office may vary from one end of the scale, the more traditional offices-and-corridors building with steel-reinforced concrete floors, to the other, a large open-plan office covering the entire floor of a building. In the former case, the radio attenuation between offices and between floors probably will be so great that most radio cells may have no more than a 20m radius. In the latter case, a single strategically sited cell may be able to maintain radio coverage of an entire floor of the building and perhaps the floors above and below as well. For outdoor public systems, you can find equally extreme situations.

Environment-related variable attenuation is not the only problem with getting adequate radio coverage. Radio propagation at the DECT and PWT frequencies also is subject to multipath fading, where multiple radio reflections add up in or out of phase to increase or decrease the radio signal at any one point (Figure 8.2). That leads to unexpected local dropouts in which the radio signal falls below the sensitivity limit of the radio receiver.

These unexpected dropouts lead to the actual radio range being somewhat less than the range anticipated from the receiver's measured sensitivity and the ideal free-space signal-loss curve. For that reason, a fading margin usually is applied in radio coverage planning, which is, in effect, a reduction of the actual sensitivity to an apparent sensitivity that covers the dropouts. That prevents the appearance of pockets of poor or absent radio coverage.

### 8.3.2 Cell-Site Planning

Because of the extreme variations in radio environments, planning the placement of RFPs is not an exact science. The "kitchen-planner" approach with a

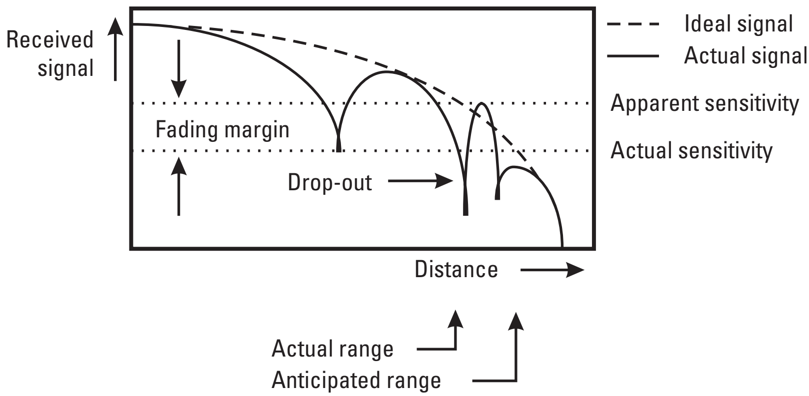


**Figure 8.2** Fading margin.

plan of the building or the district and a categorization of the radio environment on a scale ranging from "easy" to "difficult" can be made to work but often leaves too many radio coverage holes, especially if you are trying to be reasonably economic with the number of cell sites. Remember that each cell site represents a significant investment in the following:

- Installation manpower;
- Equipment at the cell site;
- Wiring from the cell to the central controller;
- The cell's share of equipment at the central controller;
- The cell's power supply (either local or via the wiring from the central controller).

Compared to the kitchen-planner approach, a better installation usually is achieved with a field deployment tool that measures the actual radio coverage from a portable RFP placed at a candidate cell site. The limit of coverage is where the signal from the portable RFP drops below the terminal's apparent sensitivity, as experienced by a user. To determine that, you can start with the –86 dBm figure required of a GAP-compliant handset (–90 dBm for PWT), but you must allow for multipath fading (perhaps 12 to 18 dB) and some overlap between cell edges (about 3 dB is probably reasonable if the system has seamless handover and the extra handover traffic is acceptable; 6 dB otherwise). The trade-off here is that the engineering manpower required to do such a survey is greater than that needed with just a building plan, an installation guide, and a pencil.

RF safety is another matter you need to consider when planning cell sites. Unlike a normal portable, which may transmit on normal power (250 mW) for just one timeslot every 24, the RFP may be communicating with several handsets and may also have a directional antenna. In most normal cases, safety does not present a problem, but annex A of the DECT PHL standard [9] does give guidance on safety distances.

### 8.3.3 System Capacity

With a single cell, you may have up to 12 duplex radio channels available per RFP. Cheaper RFPs with perhaps a slower RF synthesizer may be able to use only six. Other limitations may apply, such as the connection between the RFP and the controller, which may have to transport data a couple of kilometers in big systems. For example, it may be economic to provide only backhaul capacity for up to eight duplex radio channels over long signaling links. Regardless of the limiting factor, there will be a limit to the maximum number of duplex radio channels that can be handled by a single RFP.

Providing coverage in a cell requires the deployment of at least one RFP, but capacity considerations may then dictate that more than one RFP be sited within that cell. An RFP with a 12-channel capacity and a 12-channel backhaul link will provide 5.3 Erlangs of capacity (Table 8.2) at a 0.5% grade of service (GoS), that is, there is a probability of 0.5% that any particular call cannot be made because no radio channels are available. That particular number can be looked up in the Erlang B tables under the 12 trunks column and then locating the capacity for a 0.5% GoS figure. The better the GoS (i.e., the smaller the GoS number), the smaller the capacity in Erlangs available from the 12 channels.

It is typical to plan for office systems on the need for about 0.15E of traffic generated by a user's terminal. Roughly speaking 0.15E means that the user

**Table 8.2**
Number of Users Served Versus Available Base Station Channels

| Available Channels | Total Capacity at 0.5% GoS (Erlangs) | Users at 0.05 Erlangs | Users at 0.10 Erlangs | Users at 0.15 Erlangs |
|---|---|---|---|---|
| 12 | 5.3 | 106 | 53 | 35 |
| 8 | 2.7 | 55 | 27 | 18 |
| 6 | 1.6 | 32 | 16 | 11 |

of the terminal spends 15% of the time on the telephone. Experience shows that reality sometimes can vary greatly from that “average” and a real deployment situation will have to be carefully assessed.

However, at 0.15E per user, the 5.3E capacity of a 12-channel RFP can serve 5.3/0.15, or about 35 users. If the RFP has a slow synthesizer and can use only 6 channels instead of 12, the capacity drops more than you might expect, supporting only 11 users. In those sorts of environment, it may be more economic to use better quality synthesizers in the RFPs than to deploy colocated RFPs to get the required capacity.

In a big open-plan office, a cell diameter may reach 100m (an area of about 8,000 $m^2$), perhaps more. The number of potential users within that area easily could exceed 35 (at 20 $m^2$ per user in an office full of desks, there might be 400). If so, the number of channels in the cell has to be increased, or the size of the cell has to be decreased and more cells put in to provide the service.

Often, increasing the number of RFPs within a cell is easy. First, there is a site at which the original cell is located. That usually will be able to accommodate a second RFP, and the wiring to the controller has to go to only one spot. Also, if external power has to be supplied to the RFP (rather than through the telecommunications leads), there usually is power available already. However, reducing the size of a cell usually is the best way to increase capacity. That is because at any point the signal strength available from a cell usually is greater, since you are nearer the center of the cell. Also, it means that the capacity of neighboring cells may be available to users within a cell in the event the current cell’s capacity ever does get used up completely.

There is a disadvantage to shrinking cells in that the radio interference background increases due to the proximity of the other cell sites. Nevertheless, up to a point, where the cell may be as small as 15m in radius, the system’s channel allocation algorithm will cope with finding channels to use that are sufficiently clear of interference. However, the disadvantage of splitting the cell is that more sites have to be found with wiring back to the main controller and perhaps extra power supplies. The cost of installing a power supply at any point may add significantly to the cost of installing the cell, so line powering of the base stations often is an attractive option when overall installation costs are taken into account.

### 8.3.4 Incoming Calls (Paging)

When planning a big cordless PABX or any other high-capacity system, you may need to think about incoming-call traffic and whether to divide the system into multiple clusters (see Section 5.2.6).

Paging traffic is carried simultaneously on the beacons of all cells within a cluster (see Section 5.5.6). That means you normally get the capacity to issue just six pages per 160-ms multiframe (see table 5.8), or 37.5 paging messages per second. The pages may have to be repeated if the handset is not responding or is missing the message for some reason, so the real capacity is somewhat lower. Fortunately, only a reasonably big system with a lot of heavy users may have to handle as many as 10 incoming calls per second during the busiest periods. Nevertheless, if your system has to handle anywhere near that level of call arrival, you need to divide it into clusters and assign separate LAL identities to split up the paging load.

## 8.4 Identities, Addressing, and Security

The identities of portable and fixed systems are things that a system manufacturer, installer, or user has to manage for a DECT or PWT system to function properly and with security.

The identities of complete fixed systems (see also Section 8.4.3) are called access rights identities (ARIs) because they are used by portables to determine if they have access rights to the system. In simple cases (such as residential telephones and very small PABXs), those identities are fixed and set up by the manufacturer. In more complex or bigger systems (e.g., bigger PABXs, interconnected systems, or public access systems), the identities are loaded into the system by the installer or operator. In all cases, the identities are then broadcast by the fixed system on its beacon. It is important to note that when systems are loaded with identities, they really are the identities of the service offered, not necessarily the system offering it. It is entirely possible to load the same sets of identities into two completely different systems, provided they both offer the same service.

Complete system identities are subdivided so that individual cells (RFPs) within the system may be identified. That is done by allocating each RFP an RFP Number (RPN). That also allows groups of cells to be identified together as location areas, which may be used to manage the way in which portables are tracked as they move.

When a portable is given access to a fixed system, the fixed system's ARI is given to the portable. The portable stores the ARI for future reference, in which form it is called a PARK. The portable also is told how many bits of the PARK must be checked against a broadcast ARI to determine if the portable has access rights to the system. If the portable later hears a system broadcasting an ARI, it can compare the ARI with any PARKs it has stored. If there is a match to at least the specified number of bits specified by the PARK length indicator (PLI), the portable knows that it will be able to gain access to the system and can then attach to the system to make sure the system knows it is there.

The identity of a portable itself may be one of two types. The first is the unique hardware serial number of the portable, the IPEI (international portable equipment identity). It is possible for a fixed system to regulate access based on the portables' IPEIs, but then only certain pieces of equipment, rather than certain users, are allowed access a fixed part's services. This is not sufficient for all applications. It is therefore possible to assign an identity to the portable (when it is given access to a system) that is there to identify the portable's user rather than the hardware. Those kinds of identity are the IPUIs (international portable user identities). The portable may be given an IPUI at the same time the portable is given the fixed system's PARK and PLI. If the identities are stored inside a DECT smart card (a DECT authentication module), the user may transfer an identity from portable to portable. If the user travels and uses different equipment in different locations or if equipment has to be replaced, the user's identity remains and the service continues.

The portable's complete identity (as far as accessing a given service is concerned) is a combination of its stored IPUI + PARK + PLI. However, a portable also may be given a TPUI (temporary portable user identity) when it successfully attaches to a fixed system after recognizing the fixed system's ARI. The TPUI is used to save bandwidth when the portable is paged as a result of an incoming call. Paging messages can address a portable by its IPUI, but the TPUI is shorter and uses up less bandwidth. This state of affairs is illustrated in Figure 8.3.

### 8.4.1 Portable-Hardware Identities

Every portable is unique. They are each assigned a 36-bit hardware identity at manufacture that cannot (or should not) be changed during the lifetime of the

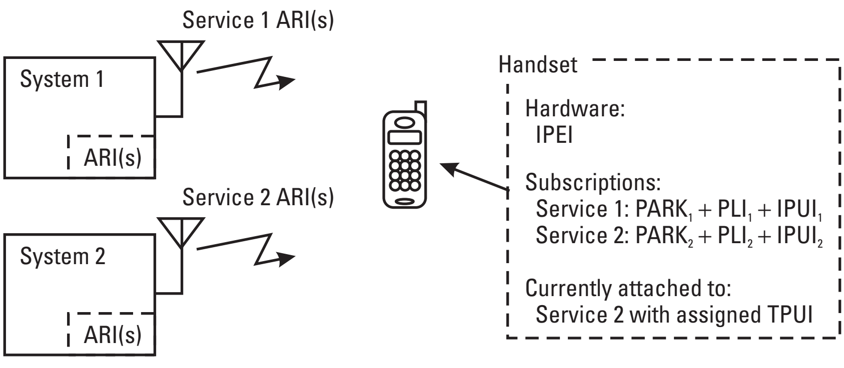


**Figure 8.3** Storage of system identities.

hardware. That identity is the IPEI, as shown in Figure 8.4(a). It has a standard textual representation for printing on a label or for displaying on the portable's (or any other) display device.

The first 16 bits of the IPEI, the equipment manufacturer code (EMC), is allocated by a standards body to be globally distinct for each manufacturer. In the case of European manufacturers, an EMC may be obtained from ETSI (see the glossary for contact details). For the United States, ETSI also acts to allocate those identities.

The remaining 20 bits allow a manufacturer to allocate a unique serial number to each of just over one million handsets or other portable terminals. A company that makes more equipment than that needs to get another EMC. A manufacturer should never rely on identifying its own equipment by the first EMC it is allocated.

### 8.4.2 Assigned Portable Identities

As well as having a fixed electronic identity, a portable also is assigned an identity to use when it is registered to use a service. The identities must be stored in the portable for future use in accessing services. The assigned identity is keyed into the portable or downloaded via an on-air subscription process.

A single portable may have many different assigned identities, one given to it by each service with which it is a registered user with access rights. Actually, it is not really the portable equipment that is assigned the identity when registration takes place but the portable's user; that identity is the IPUI, as illustrated in Figure 8.4(b), which may take several different forms depending on its use.

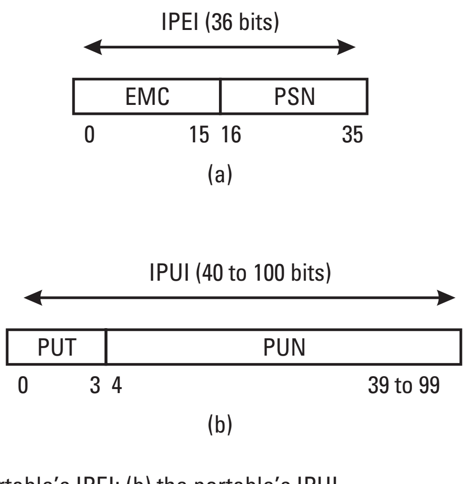


**Figure 8.4** (a) The portable's IPEI; (b) the portable's IPUI.

It is possible that the assigned IPUI is stored in the portable in a memory that is not separable from the equipment. In that case, the user and the equipment are not separable. However, with the use of a smart card with DECT-specific storage, a DAM, it is possible for a user's identity to follow that user from one handset to another. The different IPUIs are listed in Table 8.3.

A portable that is otherwise unregistered uses the default IPUI of type N. For residential systems, IPUI type N may be the only IPUI the portable ever has.

### 8.4.3 Fixed-System Identities

Every fixed-part radio in a DECT system broadcasts a beacon on which is carried one or more fixed-system identities (ARIs). The broadcast mechanism that allows that is described as a vertical thread of procedures and data structures in

**Table 8.3**
International Portable User Identities

| IPUI Type | Use |
|---|---|
| N | Residential systems and default use (for small systems) where the hardware identity, the 36-bit IPEI, is enough to identify the user. |
| S | General PSTN/ISDN use, where the identity is a 60-bit binary-coded decimal PSTN, or ISDN telephone number. |
| O | Standalone private system where the identity is a binary-coded decimal telephone number (60 bits), possibly significant only to the local network. |
| T | Extended private system where roaming is supported over several private networks. The identity is a combination of the 16-bit equipment installer code (EIC) and a 44-bit binary-coded decimal telephone number, possibly significant only to the local network. |
| P | Public or public access system (including RLL) where the identity is a combination of a 16-bit public operator's code (POC) and an 80-bit binary-coded decimal account number. |
| Q | General public access system where the identity is an 80-bit binary-coded decimal bank account number to which charges for service are made. |
| U | General public access system where the identity is an 80-bit binary-coded decimal credit card account number to which charges for service are made. |
| R | Public GSM-connected system where the identity is the subscriber's GSM identity, a 60-bit international mobile subscriber identity (IMSI). |

Chapters 3 through 7. One of the broadcast identities is selected by the system installer or operator as the system's primary ARI, PARI, which is broadcast the most frequently. The system is allowed to broadcast secondary ARIs, SARIs, which are broadcast less often than the PARI. You might, for example, want to broadcast a SARI if you have an arrangement with a neighboring company to allow their employees to use your PABX. In that case, their PARI would be programmed into your system and broadcast as a SARI. It is also possible to program tertiary ARIs, TARIs, which are not broadcast but available only when a portable asks for the system's TARIs.

The fixed part's ARIs are derived from some basic information about the fixed system, its purpose, and its capabilities. The main issue is that the manufacturer of a system has to decide into which class its equipment falls. That is shown by the first three bits of the ARI (Figure 8.5). The remaining bits of the ARI vary according to the ARI class.

Broadly (but not exclusively), systems fit into up to eight classes, of which six currently are allocated as shown in Table 8.4. A residential single-cell cordless telephone set, for example, is best classified under class A. Part 6 of the DECT standard, "Identities and Addressing," [10] shows that ARI class A comprises three bits identifying the ARI as a class A ARI (the access rights class or ARC) plus 16 bits called the equipment manufacturer's code (EMC), which a manufacturer must obtain from ETSI, plus 17 bits called FPN (fixed part number), which a manufacturer must allocate uniquely (avoiding FPN = 0) to provide a unique hardware-related ARI.

### 8.4.4 Identities for Location Areas Within a Fixed System

Many cordless systems are small enough not to need any more than one identity for the entire system. Sometimes, however, you do need to distinguish one part of the system from another. To do this, the fixed system's identities are augmented by taking the PARI, tagging on to it the identity of the cell in which it is being broadcast, and adding one more bit to say whether any SARIs are

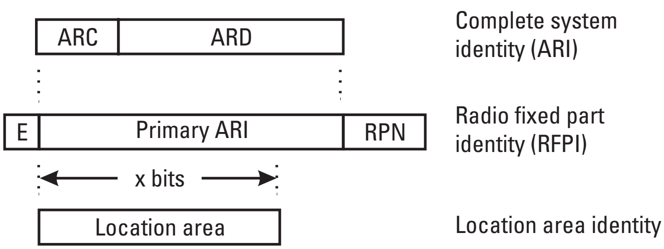


**Figure 8.5** The fixed system's identities.

**Table 8.4**
Fixed-System Identities (ARIs)

| Class | System | SARI or TARI? |
|---|---|---|
| A | Residential or small private PABX, from one to seven cells. Identities are preconfigured and based on fixed hardware identities, which change if any equipment is replaced. The fixed identity contains an EMC, which must be obtained from ETSI. | No |
| B | Larger multicell private PABX, where the identities are programmed. The identities include an ETSI-assigned EIC as well as an EMC. | Yes |
| C | Public telephony systems. The identity contains a POC, which is assigned by ETSI. | Yes |
| D | For public GSM-system operators who allow their subscribers to use DECT to access their networks (see Section 8.9). | Yes |
| E | Portable-to-portable direct communications (private). | Yes |

available for the system (see Figure 8.5). That creates the RFPI, which identifies a specific cell within the system.

If it is important to define different location areas within a system to manage portable mobility, the portable is told, when it attaches to a system, the number of bits from the PARI to look at to determine which location area it is in. That allows location areas to comprise a number of cells, depending on how many bits of the PARI are assigned to the location area.

Whenever the portable strays outside its current location area, which can be determined by looking at the system's RFPI as broadcast from the best cell, it is required to perform a location update to inform the system of its new location area.

### 8.4.5 Authentication

The authentication of a DECT or PWT system is based on establishing that the system has knowledge of a secret key without the key being transmitted over the radio interface. Just how the key gets to the system without anyone else seeing it is not primarily the role of the protocols, although it is critical to the real security of the authentication. However, verifying the key without revealing it is a part of the standards.

In principle, authentication of a handset can occur at the start of any call and also can take place regularly within that call. The first authentication establishes the bona-fides of the handset; later authentications establish that the link has not been taken over by an intruder.

The basic principle for authentication of a handset (Figure 8.6) is that the secret key is held in secure storage. The base station knows the key, but instead of asking for the key to be sent in-clear, it "challenges" the handset to authenticate by sending it a random number. The authentication key is used to encrypt the random challenge, and the result is sent back to the base station.

The base station, knowing the random challenge and the secret key, performs the same action as the handset and compares the handset's response with its expected response. If the two match, the base station may reasonably assume that the handset knows the secret key.

Although the algorithm for encrypting the challenge with the secret key is not a secret, it is constructed carefully so that knowing the response and the random challenge does not give any clue about the key itself. Calculating the key knowing the challenge and the response is just too computationally expensive to work. Similarly, since there are many possible different responses, in principle a different one for each of the many possible challenges, it is no good listening to the responses and trying to respond with one you already have heard. The same challenge will never be repeated in any reasonable time.

The algorithm, the DSAA, is not a secret. However, it is not revealed to anyone without their signing a nondisclosure agreement to limit the algorithm's exposure to malicious cracking attempts. It may be obtained by contacting ETSI, which will indicate the current arrangements for obtaining the documentation.

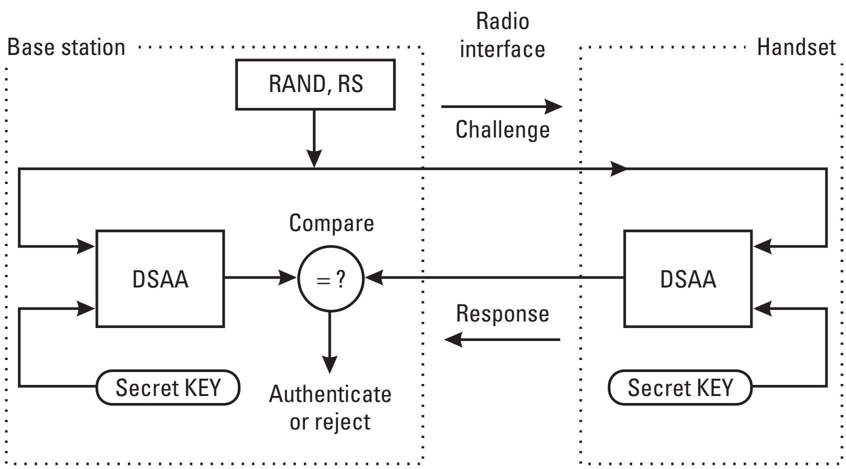


**Figure 8.6** Handset authentication.

### 8.4.6 Encryption

The DECT system is designed to use the same algorithms it uses to perform authentication to derive session keys to perform encryption of the C-plane (signaling) and the U-plane (speech/data). The exact details of the process are given in ETS 300 175-7 and are not reproduced here.

## 8.5 Wireless ISDN

As presented to most users, ISDN appears as a digital signaling channel (a D-channel) of 16 kbps with two user channels (B-channels) of 64 kbps each. Wireless support for this 2B+D service is what we describe here.

There are actually two standardized ways in which the protocol provides interworking of ISDN equipment over the air interface, which are illustrated in Figure 8.7:

- End system configuration (see ETS 300 434 [6]), where the fixed part and the portable part together emulate a standard ISDN terminal;

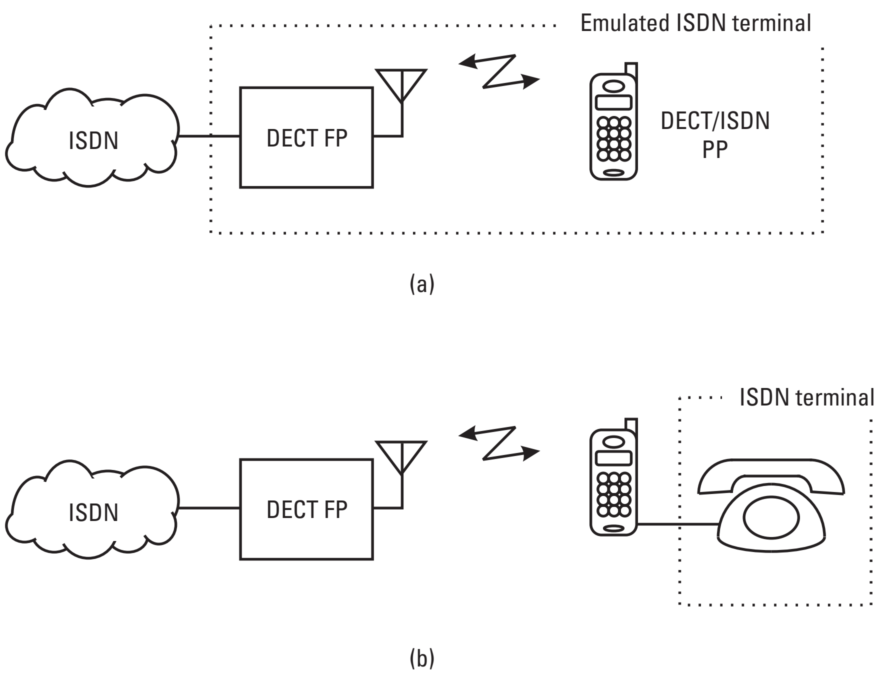


**Figure 8.7** (a) DECT/ISDN end-system; (b) intermediate system.

- Intermediate system configuration (see ETS 300 822 [7]), where you can put a socket on the side of a cordless terminal into which you can plug a standard ISDN terminal.

In the first configuration, the ISDN protocol is terminated at the base station; in the second, the protocol passes through the base station and handset to be presented and terminated beyond the portable, very much like providing a radio local loop terminal with a remote ISDN socket.

The general method by which DECT carries ISDN is to define the following:

- How ISDN's two 64-kbps B-channels and its 16-kbps D-channel are mapped onto data packets at the air interface;
- How the cordless protocol stack interworks with the ISDN protocol stack;
- The means to keep the error rate in the B-channel low and comparable to that expected in a wired ISDN context.

DECT/ISDN systems need to use more of the base standard's procedures than do normal analog telephone systems. Upgrading a normal GAP- or CPAP-compliant telephone to handle ISDN is a reasonably extensive task, since you have to add support for the protocol's advanced procedures.

### 8.5.1 The ISDN End System

The ISDN end-system configuration is one in which the base station attaches to an ISDN basic rate (2B+D) interface, and the fixed system plus the portable act together to form an end system that has the behavior of a normal ISDN terminal. The ISDN protocol terminates at the base station. For its user traffic (e.g., speech), the portable is given managed access to the ISDN B-channel(s). It is the base station that translates the normal over-the-air control signaling into ISDN signaling and vice versa, to give the portable access to ISDN's features. To carry out the process of adapting the cordless protocols at the top of the protocol stack to ISDN, there is a specified interworking unit in the base station, as shown in Figure 8.8(a). The IWU maps the air interface's layer 3 messages onto the ISDN interface in both the send and the receive directions. There is already (by design) a reasonably good correspondence between DECT's services and those of ISDN, so the IWU's functions are not extensive.

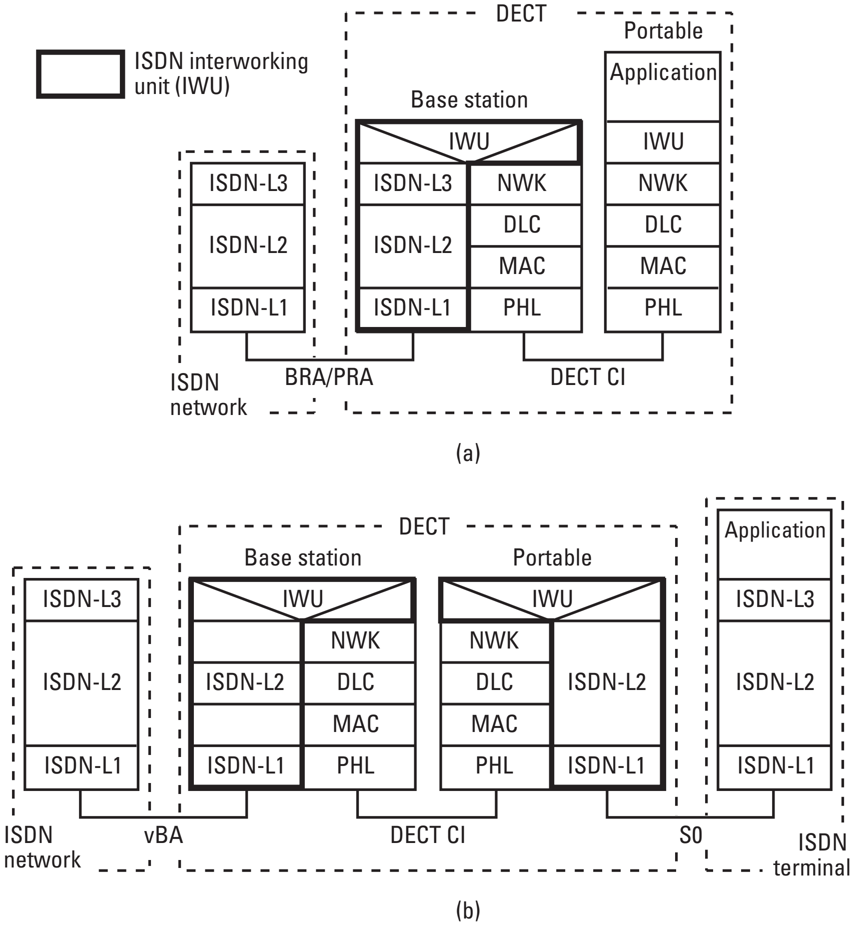


**Figure 8.8** (a) DECT/ISDN end-system protocol stack; (b) intermediate system protocol stack. *Source:* ETSI [6,7].

In that configuration, the user's supported bearer services are as follows:

- Speech;
- 3.1-kHz audio;
- Unrestricted digital information at 64 kbps.

Applications using those bearer services may include normal 3.1-kHz telephony, 7-kHz telephony, group 4 fax, teletex, videotex, and voiceband data transmission such as group 3 fax and modem data transmission.

### 8.5.2 The ISDN Intermediate System

The ISDN intermediate system configuration is one in which the portable part provides a socket (an S-bus) into which an ISDN terminal can be plugged. It thereby gains access to ISDN and its features over the cordless air interface. Both public ISDN and private ISDN are supported. In this case, as shown in Figure 8.8(b), a specified ISDN IWU exists within both PP and FP, which maps ISDN layer 3 messages bidirectionally to and from the air interface. The IWUs are specified to give the ISDN user transparent access to ISDN services and functions. A larger list of bearer services is supported, compared to the end system, including the following:

- Speech;
- 3.1-kHz audio;
- Unrestricted 64-kbps data;
- Packet data;
- User signaling bearer service.

### 8.5.3 ISDN and Radio Capacity

One of the basic things to grasp about ISDN in this context is that in normal fixed ISDN basic rate interfaces the PHL (the wire) is not shared, and the available bandwidth is always 144 kbps even if only one of the 64-kbps B-channels is to be used for a call. In a shared radio environment such as DECT (or any other wireless access technology), it is not acceptable to tie up 144 kbps of capacity for two B-channels and a D-channel if only one B-channel is to be used. The procedure for setting up a normal call on ISDN is to establish layers 1 and 2 of the ISDN protocol before the layer 3 protocol message may be sent asking for the specific service needed. That is the first point in the call-setup procedure, that you get an idea of how much bandwidth is really needed. For DECT therefore, it is the ISDN layer 3 message that determines the amount of radio spectrum to be used for the call.

When the bearer service requested is 64 kbps unrestricted digital information, the DECT or PWT system sets up just that, a 64-kbps channel based on the LU7 service at the DLC. The LU7 service uses buffering and retransmission and occupies more than 64 kbps on the air interface to be able to provide some error correction to compensate for radio propagation problems. Since the user's bearer service is labeled "unrestricted," we have to give it a full 64-kbps radio bearer of the best possible quality. However, in the case that the user's bearer service is for speech, it is permitted to save radio bandwidth by transcoding the

ISDN 64-kbps speech channel into 32 kbps using the standard ADPCM encoding. In that case, no extra error protection is provided over and above that normally provided by DECT.

### 8.5.4 ISDN B-Channel Carried Over the LU7 Service

The requirements for error performance in ISDN services are specified by the ITU-T in Recommendation G.821 [11]. The reader will find that the error requirements are difficult to achieve with a radio-based PHL. While the ISDN signaling (the ISDN D-channel) has its own error protection and tolerates errors even if the error control of the control-traffic plane of the cordless protocol stack were to fail, the ISDN user traffic in the B-channel has no specific error protection, and neither does the regular user-traffic plane of the protocol stack when configured by voice traffic. For that reason, a DLC-layer service is defined (see Section 6.2.3) as imporoving the error rate of the user-traffic plane of the protocol stack. It does that by using forward error correction (FEC), with an ARQ retransmission scheme for those frames of user data that still cannot be corrected. This service is called the LU7 service (see Table 6.3).

To be able to retransmit some parts of the 64-kbps B-channel if they have too many errors, the gross data rate on the air interface needs to be greater than 64 kbps. Hence, LU7 is carried over a P80 physical packet, that is, a double slot on the air interface, having 64 bits of protected signaling and 800 bits of user data (see Figure 4.5). Within those 800 bits, 720 bits (i.e., 72 kbps) ultimately are available for carrying the 64-kbps ISDN B-channel data. The 64-kbps data are buffered 80 ms at a time, sent over the LU7 service at 72 kbps and in the time remaining out of the 80 ms, the recipient asks for a retransmission of any data it cannot correct using the FEC. If there is not too much data to retransmit, the recipient will finally have all the data in its 80-ms buffer in time to send them out fully corrected. This method of keeping the error rate low introduces an 80-ms delay into the user traffic.

Technically, at the MAC layer, the unprotected multiplex U80a is used in a symmetrical single-bearer connection. That gives a raw data rate of 80 kbps to be used for the 64-kbps channel. The advanced MAC connection control and B-field signaling are used, and paging uses the full format (advanced features not covered in Chapter 5). At the DLC layer, the FU7 frame is used (Figure 8.9).

## 8.6 Data Applications

DECT and PWT have a wide range of wireless data capabilities that can be described here only in outline. A family of data application profiles ensures

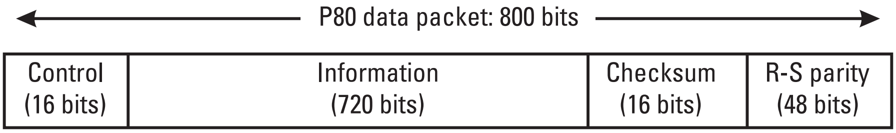


**Figure 8.9** Mapping ISDN 64-kbps service into the FU7 frame.

interoperability between products from different manufacturers for a wide range of data systems. The data applications all exploit the advanced services of the base standards that are not needed for speech but that are there for purposes such as this. Those advanced services are specifically oriented toward LAN, multimedia, and serial data capability. Each member of the data application profile family has been optimized for a different kind of user service, and distinction is made between services without mobility (called class 1) and those with mobility (called class 2). The different data profiles are modular and closely related, so they can be implemented economically and efficiently either independently or in combination. The services and relationships of the different profiles are fully described in ETR 185 [12], and some of the capabilities are illustrated in Figure 8.10.

The data profiles provide security (authentication and encryption), call charging, flexible throughput up to 552 kbps, high reliability, error correction, and other features, thus making them suitable for public wireless data services as well as data services in the private and business environments. Although it would be impossible to do justice to the entire range of data applications here, the family of applications comprises the members briefly described next.

### 8.6.1 Generic Frame Relay Services

The generic frame relay services, where frames of data are transferred with their boundaries preserved but without any notification of receipt, are the basis for all the connectionless data services defined by the protocol. The basic standard for the interworking of nonmobile application to connectionless networks within closed user groups is the ETS 300 435 data services profile [14], which defines service types A and B, class 1. It defines a basic frame relay service and then includes annexes for interworking with Ethernet and token ring LANs at a throughput of up to 552 kbps. The distinction it makes between type A and type B services is based on maximum throughput. The type A service is simpler and uses fewer of the base standard's features but has a maximum throughput of 24 kbps. The type B service uses more of the protocol's optional lower-layer

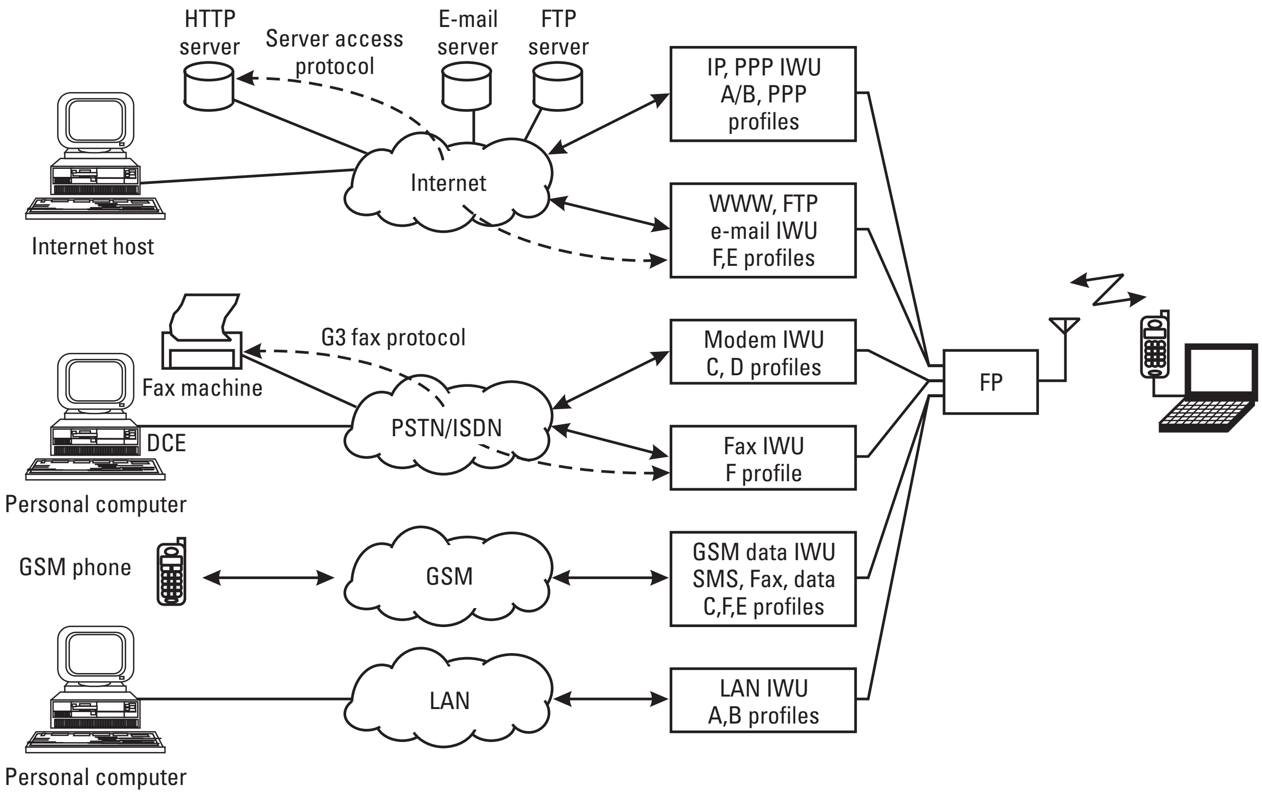


**Figure 8.10** Data capabilities. *Source:* ETSI [13].

capabilities but has a maximum throughput of 552 kbps. In providing the higher throughput rates, it uses larger packets on the air interface and more of them, so equipment using type B service consumes more power.

For generic frame relay services where significant mobility is required, the basic standard is the ETS 300 701 data services profile (service types A and B, class 2) [15]. The application profile supports similar services to the class 1 but is not restricted to closed user groups. As a result, in addition to its support for Ethernet and token ring LANs, direct interworking with Internet protocol (IP) networks is defined.

### 8.6.2 Generic Data Stream Services

The type C, class 1 service defined in ETS 300 699 [16] is a nonmobile, nontransparent generic data stream service for closed user groups with high integrity. It builds on the type A and B profiles but adds a link access protocol service in the user data path (LAPU), which is similar to the LAPC protocol already defined in the DLC layer for the control path. It has provisions for packet assembly and disassembly functions for asynchronous data streams. It includes annexes for interworking with V.24 interfaces.

The mobile equivalent (class 2) is defined in ETS 300 651 [17]. It extends the data stream service into environments such as public services, where significant roaming is a characteristic. The profile contains interworking annexes to V.24 and connection-oriented bearer services. This service can be used to provide interworking with a voiceband modem service over public networks such as the PSTN or ISDN.

### 8.6.3 Point-to-Point Protocol Support

DECT and PWT have support for the point-to-point protocol, PPP [18], which provides interworking for nonvoice applications with roaming mobility, in applications such as dialup Internet access. It uses the capabilities of PPP to transport not only IP packets, but datagrams from many different protocols. It builds on the type A/B class 2 services (see Section 8.6.1) and type C class 2 (see Section 8.6.2). PPP packet transfers on the air interface are specified via a highly efficient packet transmission protocol. However, interworking to the fixed network may be via a number of interface protocols, including X.25, frame relay, ATM, traditional circuit-switched voiceband modems, or ISDN connections.

### 8.6.4 Mobile Multimedia Support

The ETS 300 755 data services profile [19] is a multimedia mobile messaging service with specific provision for facsimile services (service type F, class 2). It creates high-level interoperability for a range of services, including fax, e-mail, WWW, HTTP, and FTP. It does that through a multimedia file transfer mechanism built on the generic data stream service (see Section 8.6.2), with full support for roaming and public access. One of the main applications of this profile is to provide interworking to public and private group 3 fax services.

### 8.6.5 Low-Rate Messaging

The low-rate mobile messaging service (service type E, class 2) provides a means for the low-rate and low-power-consumption transfer of different types of messages, including alphanumeric paging messages and the transfer of multimedia message objects. The ETS 300 757 data services profile [20] provides both point-to-point and point-to-multipoint messaging through the signaling channel, with and without acknowledgment, based on the multimedia messaging service (MMS) specified in ETS 300 755 [19]. Because it uses only the control plane, it can easily coexist with applications delivering voice service, such as a GAP handset. No user-plane functions are required, so there is no interruption of the voice service. This service can be used for applications that provide private and public roaming message services, such as the GSM SMS [21].

### 8.6.6 Isochronous Data Bearer Support

The D2 profile [22] is suitable for transparent, isochronous transfer of synchronous data streams and is intended for use in private and public roaming applications. Different qualities of service are specified from unprotected to fully protected, providing different levels of error performance and different levels of complexity. Interworking to isochronous modems and standard synchronous circuits is the aim of this profile as well as video telephony, video conferencing, and end-to-end encrypted telephone services over external networks. The D1 profile [23] provides a nonmobile equivalent service to the D2 profile for closed user groups.

## 8.7 Radio Local Loop Applications

RLL generally refers to the provision of a telephony service to a “standard telephone” by use of a radio interface to extend the reach of the network providing service (Figure 8.11). The need for copper wire in the final part of the connection from the local exchange is removed, and an expensive part of the access network is eliminated. Of course, the radio installation itself can be expensive. However, it usually is assumed that, over the long term, the installation and maintenance costs of an RLL installation will work out cheaper than copper wires. In this scenario, all the cordless equipment is part of the network itself, and the network operator's responsibility normally ends at the telephone socket on the cordless terminal adapter (CTA), which is, therefore, the network termination point (NTP).

ETSI's report on DECT RLL (ETR 308 [24]) examines in detail the specific services that may be offered. It identifies the basic wired analog PSTN services that could be replaced by an RLL system and also identifies that there are market opportunities for much more advanced services and different service scenarios. For example, it is possible for the CTA to belong to the customer rather than to the network operator. In this case, the NTP is in the air interface between the fixed part and the CTA. The operator's responsibility for the system, therefore, ends with the provision of a suitable radio signal strength at some point on the customer's premises, and the customer takes responsibility for the CTA's siting, maintenance, and performance. This scenario has lower installation and maintenance costs for the operator, but with inexpert customers the likelihood is that ongoing service quality issues may arise because of bad CTA installation.

The basic RLL applications (PSTN replacement including modem applications up to 33.6 kbps) are covered in part 1 of the RLL Access Profile (RAP) [25]. More advanced applications of RLL (e.g., when the attached equipment is an ISDN terminal or an ISDN PABX) are covered in part 2 of the RAP [26], which also covers requirements for broadband packet data applications up to 552 kbps.

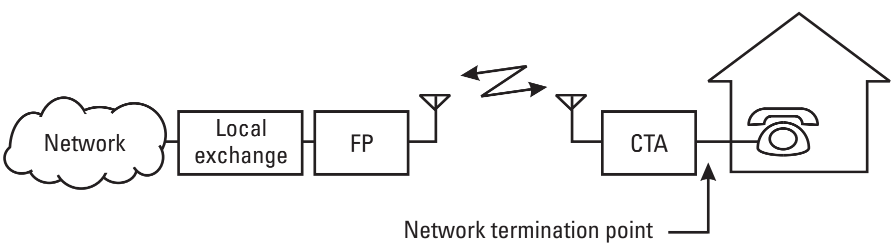


**Figure 8.11** Basic RLL service delivery scenario.

### 8.7.1 Basic RLL Applications

In general, the "portable part" of an RLL system, the CTA, is not really portable in the sense of a normal cordless portable part. Usually, it stays in a fixed location. Also unlike most normal terminals, a CTA could provide multiple remote analog lines, suitable for interfacing to a PABX. Basic RLL service requires a CTA that is closely based on GAP, with minimal changes and additions. The basic changes are as follows:

- Some user-originated signaling information (e.g., pulse dialed digits and register recall) and some local exchange–originated signaling (e.g., meter pulses and line reversals) need to be specially transferred across the air interface since the ADPCM-encoded channel cannot carry it.
- GAP features not relevant to RLL (e.g., partial release) need to be removed.
- Call clearing is modified to meet the requirements for the emergency services to take control of clear-down in emergency calls.
- Support is added for the automatic invocation of a 64-kbps bearer service to enable the use of fax and modems (up to 33.6 kbps), since 32-kbps ADPCM is not transparent to modem protocols above certain limits.
- Features to allow for operations administration and maintenance (OA&M) are added.

Note that, although it is based on GAP, an RLL CTA will not interwork with a purely GAP fixed part. The fixed part needs to supports the GAP and the RAP extensions.

### 8.7.2 Advanced RLL Applications

For advanced RLL services, part 2 of the RAP simply refers to existing application profiles for the optional provision of services, including:

- The DECT-ISDN intermediate system (see Section 8.5.2) for offering an ISDN basic rate service (the ISDN intermediate system standardization work will later include interworking of ISDN primary rate access, suitable for interfacing to ISDN PABXs).
- The DECT data profiles (see Section 8.6) for providing Internet access, modem support; and group 3 fax support.

For speech service, RLL applications have the same spectrum efficiency as all other cordless services using 32-kbps ADPCM. For nonspeech applications, advanced RAP services provide direct efficient transfer of data without the need to digitize modem signals. That is much more spectrum efficient than, for example, modem signals over 32-kbps ADPCM. For packet-oriented applications, the data profiles allow for the air interface resources to be released when there are no data to send, providing even better use of the spectrum.

In addition, features have been introduced into the advanced RAP application profile for the OA&M of CTAs supporting these services. The OA&M features are largely an extension of those defined in the basic RLL services profile.

### 8.7.3 Service Delivery Scenarios

The basic service scenario in Figure 8.11 (wherever the NTP lies) is by no means the only possible way to use DECT or PWT to deliver fixed services. Two more are shown in Figure 8.12, and many more are possible (see ETR 308 [24]). In Figure 8.12(a), the radio repeater, the wireless relay station (WRS) might be used to extend the range of the basic RLL system.

The cost of an RLL system strongly depends on the cost of base stations, their sites, and the wiring of the sites. In covering difficult subscribers (from a radio propagation point of view), it may be easier to use a repeater (where a network connection to the repeater site does not have to be provided) than to install a fully networked base station.

In the second situation, illustrated in Figure 8.12(b), a WRS might be built into the CTA, to offer customers cordless telephony within their premises, without the customers having to install a separate cordless telephone. In principle, the extra facilities needed to add wireless relay functions to a CTA are relatively few, and the cost of doing so is likely to be economic compared to having a separate CTA and cordless base station.

## 8.8 Wireless Relay Stations

The WRS is a special unit capable of relaying DECT radio transmissions. The WRS works by linking two radio connections working on two different timeslots. Therefore, it can extend base station coverage without requiring a network connection to a base station controller. A WRS utilizes the normal way DECT accesses the RF spectrum. The full dynamic channel allocation functionality is available to each of the links, and nominally, information is transparently relayed through the WRS.

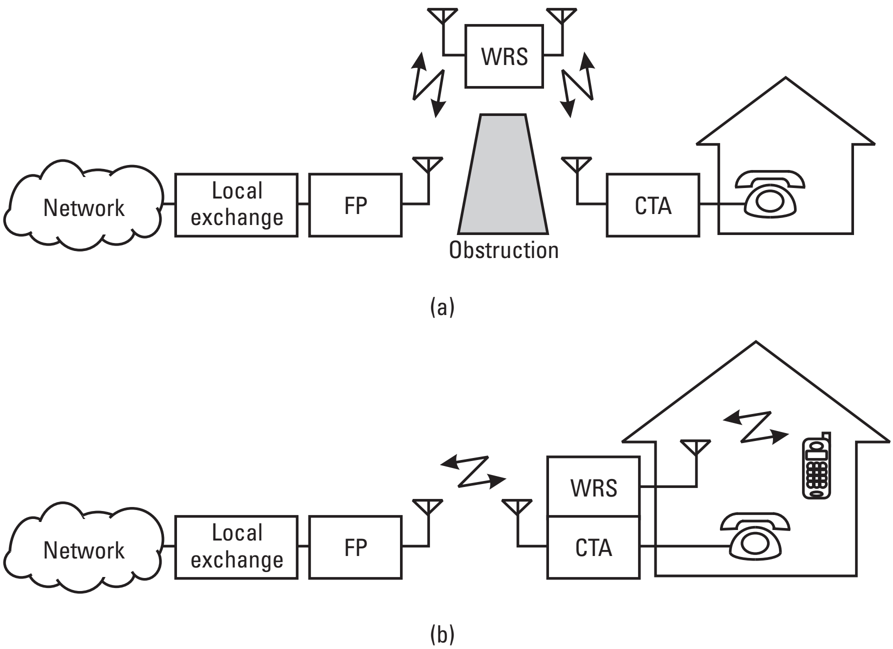


**Figure 8.12** (a) RLL delivery via a WRS; (b) combined WRS/CTA.

There actually are two ways of implementing WRSs using the DECT protocol: the "repeater part" (REP) and the "cordless radio fixed part" (CRFP). The ETSI technical report on repeaters (ETR 246) [27] and the WRS standard itself [28] provide details of the specific difference between the two types. In principle, the WRS acts toward a PP exactly as if it were an ordinary RFP, so that a PP cannot distinguish between a WRS and an RFP. Similarly, the WRS acts toward an RFP just like a portable. This principle can be used to put in place a single repeater between an FP and a distant PP or even several repeaters where the distance between PP and FP is very large.

### 8.8.1 The Basic Uses of a Repeater

The WRS is suited to providing cost-effective infrastructures. Often, it is better than using a standard base station in low-traffic-density applications, where it is used to extend or improve coverage indoors or outdoors that otherwise is marginal or to extend coverage to areas behind obstructions.

A typical application, illustrated in Figure 8.12(a), is the WRS extending RLL coverage to an otherwise difficult-to-cover area. In an RLL application, normally, a cordless terminal adapter placed at roof level might feed a standard copper pair into the residence for users to connect one or more wired telephones. In another application, instead of feeding service into the home via copper cables, a WRS used at rooftop height instead of the standard CTA can feed service into the home as a cordless radio link (Figure 8.12(b)), leading to much less wiring and the availability of cordless telephony directly, without a separate base station having to be installed. The two functions, WRS and CTA, even can be combined to economically provide both types of RLL access.

In larger residences, where traffic is normally low compared to commercial premises, it may be much easier to install a repeater to extend radio coverage rather than install what otherwise may have to be a small two-cell PABX. In general, it is cost effective to use a repeater (versus putting in another base station) where base station density and traffic are low.

A WRS can be used to extend basic GAP speech service but also can be used in conjunction with other DECT applications, including fixed systems (e.g., RLL), mobile systems (e.g., GSM), and the various DECT data services. The WRS functionality also can be particularly effective for redirecting traffic in PABXs where a base station might have the ability to cope with 12 telephone calls, but the backhaul link to the cordless controller might offer, say, only 8. The cell's extra capacity could be used to farm out excess local traffic to another cell for backhaul to the switch.

### 8.8.2 Radio Spectrum Implications

The repeater uses more radio spectrum for one link compared to the use of a base station sited at the same point (Figure 8.13). This is clear if you think of a simple duplex voice conversation. Normally, it would use just two physical channels, one for the uplink and one for the downlink. However, for a repeater, four channels are used.

Of course, a repeater with a simple omnidirectional antenna provides a relatively small increase in the overall coverage area of a system, since much of the repeated cell area overlaps the original cell area. However, a repeater with an antenna having a single high-gain lobe as well as an omnidirectional pattern in other directions extends the area further. Naturally, both uses add the same extra load onto the spectrum. The extra channels are now in use over much the same area, regardless of the shape of the area. As a result, some national regulatory authorities limit the use of the repeater to just one extra hop. That limit is also set forward in TBR 10 [29], but national authorities may extend it.

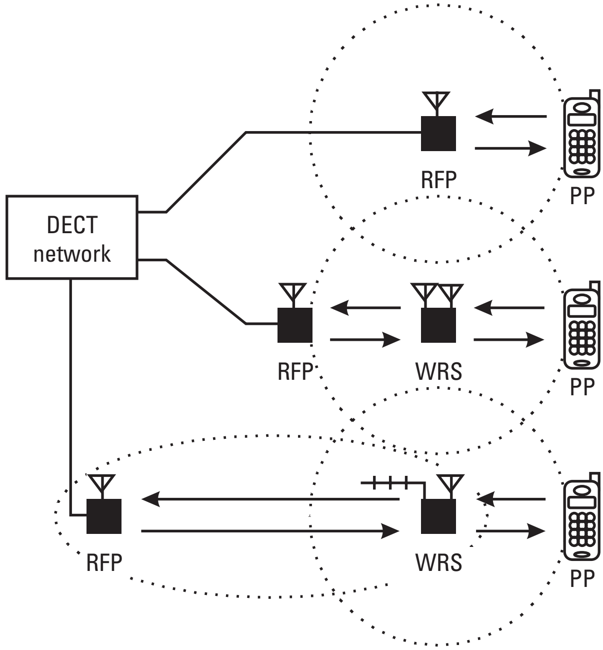


**Figure 8.13** Additional radio spectrum used by a WRS.

### 8.8.3 Transmission Delay

Because the WRS does not retransmit in the same timeslot as it receives, a small transmission delay is always introduced. In case of multiple WRSs working in series, the delays sometimes can add up to unacceptable lengths. The two WRS types differ in the amount of delay they introduce. The addition of each CRFP into a normal B-field connection adds 5 ms in each direction. The REP adds less delay: a 2.5-ms one-way delay for any number of REPs in cascade.

Excessive delay can have serious effects on how users perceive speech quality, primarily due to electrical or acoustic echoes from certain parts of a complete end-to-end connection, notably the terminations of two-wire sections. Because of the way the REP-type WRS works, any number of relays in series is tolerable. However, even with the CRFP form of the WRS, one radio relay is considered tolerable within the standard DECT echo-control system; for two or more in series, the essential additional echo-control mechanisms are specified [5].

As for data connections, delay sometimes can be critical. In many cases, however, a few extra milliseconds make little difference. Because of the many types of data connection and the plethora of applications, it is not possible to generalize in the same way as is possible about speech. An individual assessment is needed about the effect of relays on each application.

## 8.9 DECT/GSM Interworking

The treatment here of such a complex application as DECT/GSM interworking cannot be more than superficial, and there is a full ETSI technical report on the subject [30]. However, there are three basic ways to combine DECT systems with GSM:

- Using a dual-mode DECT/GSM handset where the DECT and GSM fixed systems are not interconnected;
- Connecting a DECT fixed system to a GSM system (GSM900, DCS1800 or PCS1900) through its A-interface;
- Connecting a DECT fixed system to a GSM system through an enhanced ISDN interface.

There are many other enhancements to the above scenarios, two of which we cover here:

- Using a dual-mode DECT/GSM handset where the DECT and GSM fixed systems are also interconnected;
- Using the mobility features of the GSM fixed system to support DECT-only networks.

### 8.9.1 Dual-Mode DECT/GSM Terminal With Independent Fixed Systems

One of the simplest ways to take advantage of a combination of DECT and GSM is simply to have a hybrid DECT/GSM handset (Figure 8.14). In that scenario, there is no direct connection between the GSM cellular network and the DECT cordless system. A user would have a normal GAP-compliant DECT cordless handset that is physically integrated with a GSM terminal. The portable parts would share case, display, keypad, battery, and, in the case of a DCS1800/DECT dual-mode terminal, perhaps much of the radio subsystem. The terminal has two subscriptions: one in a GSM subscriber identity module (SIM) and one in a DECT authentication module (DAM). The two subscriptions might be combined in one smart card.

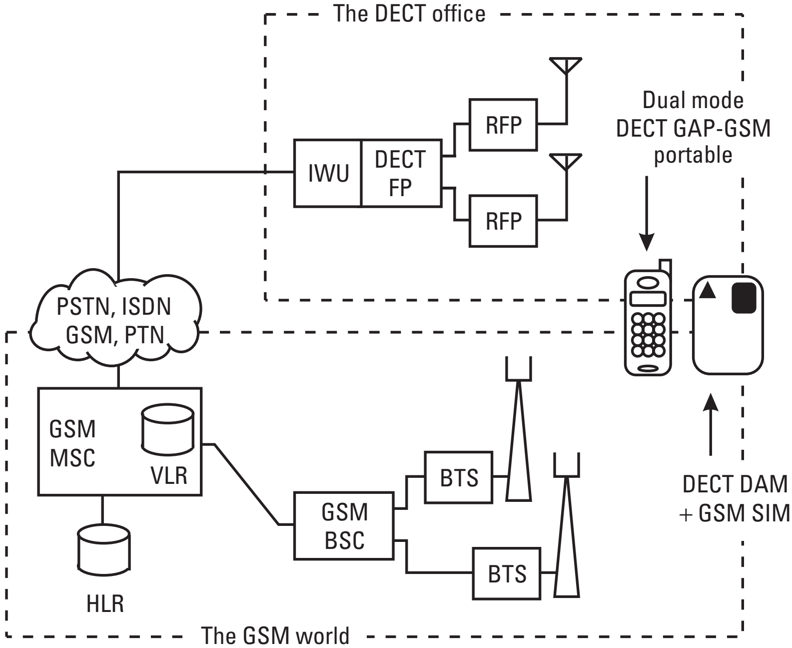


**Figure 8.14** DECT/GSM dual-mode terminal without network interconnection. *Source:* ETSI [30].

In the first instance, there need not be any coordination between the DECT and GSM parts of the terminal. The user manually selects which of the systems to use for outgoing calls and may, for example, manually set up call forwarding within the GSM and DECT fixed systems to deliver calls from one system to the other whenever there is no answer (being careful to avoid forwarding loops).

In a more complex scenario, the two applications in the same handset could communicate with each other. The handset would sense when it is in the coverage area of each system and would then automatically select which system to use for outgoing calls. When both systems are available, the handset would select whichever is either explicitly preferred by the user, or perhaps just the cheaper to use. For incoming calls, the handset would automatically set up the call forwarding service for each system, depending on its known environment.

### 8.9.2 DECT System Connection to GSM's A-Interface

When it comes to integrating DECT and GSM fixed infrastructure, the first way is to attach an FP to the GSM MSC at one of its standard A-interfaces

(Figure 8.15). That is where the GSM base station controllers (BSCs) are normally attached.

Specified IWUs in the FP and PP make the translation between DECT and GSM layer 3 protocols, according to the requirements of the GSM interworking profile (GIP). To the GSM MSC, the DECT FP looks just like a normal GSM BSC. One advantage of this method of interworking is that no changes are needed in the A-interface or in the MSCs. Nevertheless, changes to the A-interface may be needed in the future for more efficient interworking (e.g., to allow the transport of ADPCM-encoded speech and to permit DECT-specific bearer services).

The terminal that attaches to the FP is a GIP-compliant handset that accepts a SIM card. It can roam between RFPs connected to the same FP or between RFPs connected to different FPs by involving the GSM mobility management in the MSC. To change environments, the SIM can be physically moved to a GSM terminal, which then accesses the public GSM network. The GSM's mobility services possibly may notice that the equipment identity is

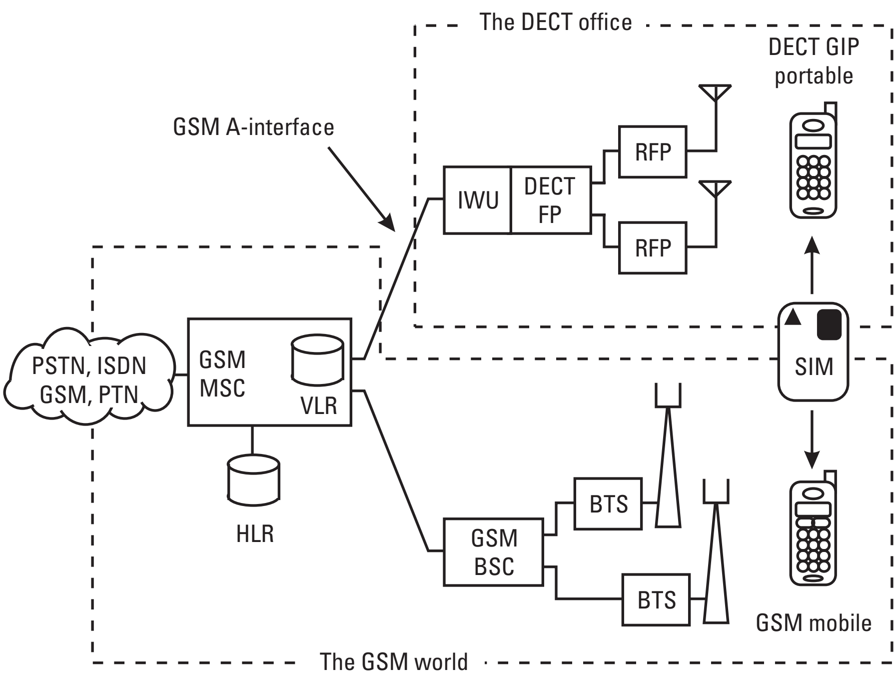


**Figure 8.15** DECT/GSM fixed-system interworking at the GSM A-interface. *Source:* ETSI [30].

different, but service that follows the user identity in the SIM card is completely transferable between the DECT and the GSM handsets.

### 8.9.3 DECT System Connection to GSM Via an ISDN Interface

The second method of integrating DECT and GSM infrastructure is to make the connection between the DECT system and the GSM network via ISDN (Figure 8.16). This method of interworking is particularly suitable for connecting DECT PABXs, which normally support a DSS1 network interface but not the GSM A-interface.

The original Digital Subscriber Signaling System No. 1 (DSS1) interface alone does not support authentication and mobility management, but ETSI has defined those enhancements, along with the support for other more general cordless terminal mobility functions to create the DSS1+ interface [8].

An ISDN interface between GSM network and DECT system allows GSM service providers to offer their services via existing DECT access networks that have ISDN interfaces. The DECT access network could be owned by the GSM operator and leased to the customer, or it could be a customer-

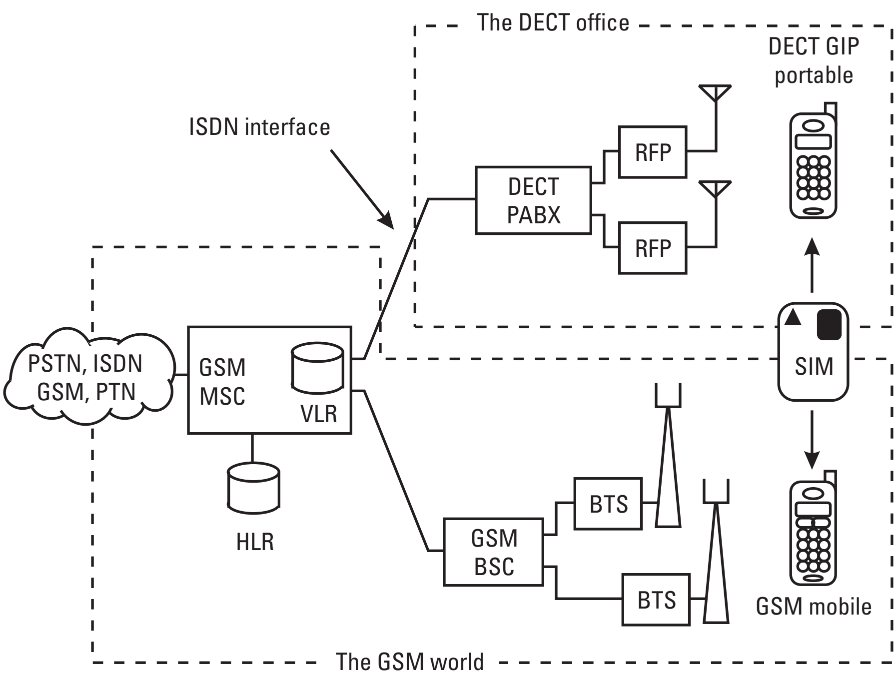


**Figure 8.16** DECT/GSM fixed system interworking via ISDN. *Source:* ETSI [30].

owned PABX or private network, which can be upgraded to provide access to GSM. By swapping the SIM between terminals, the GSM user can access telecommunication services in any location with DECT coverage where access is allowed. Local mobility is managed by the DECT system and wide area mobility by the GSM network.

### 8.9.4 DECT/GSM Dual-Mode Terminal With Interconnected Fixed Systems

We have seen how DECT and GSM systems may be interconnected via either the GSM A-interface or an enhanced ISDN interface and also how service can be obtained by swapping SIM cards between separate DECT and GSM terminals. It is, of course, also possible to use dual-mode terminals with interconnected systems (Figure 8.17). The SIM swapping between the DECT and GSM parts of the handset is, in effect, done automatically, which is much more convenient for the user.

Such a system may be useful where the GSM operator needs to add capacity in high-density areas (such as a wireless office) or where higher data rate services are needed and not provided by GSM. The capacity of DECT can be as high as 10,000 Erlang/km$^2$/floor. DECT RFPs also are expected to continue being much less expensive than GSM base stations. WRSs also may be used to improve coverage without a wired connection. Better speech quality and higher data rates are further attractions.

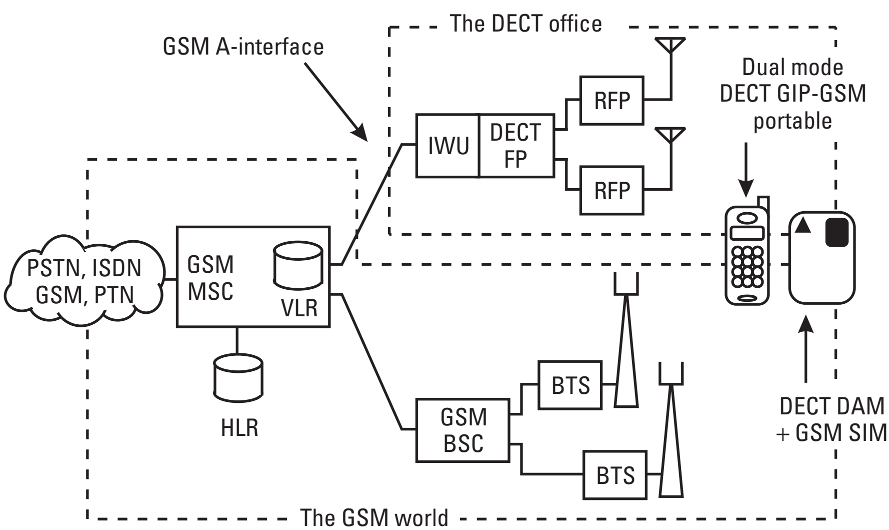


**Figure 8.17** DECT/GSM fixed system internetworking with a dual-mode terminal. *Source:* ETSI [30].

In this basic scenario, the DECT FP is interconnected to the MSC by the A-interface. The user has a GSM subscription and a dual-mode terminal and can roam between FPs and BTSs. Handover (involving the MSC) is possible between RFPs connected to different FPs, but there currently is no standard for handover between an RFP and a BTS. The DECT part of the dual-mode terminal is a GIM-compliant portable, and both parts use the same subscription (a single SIM).

The same DECT installation also can be used for RLL access to the GSM network using cordless terminal adapters complying to the RAP.

### 8.9.5 DECT-to-DECT Connection Via GSM

With the DECT/GSM interworking profiles, it is even possible to provide mobility services for just DECT systems (Figure 8.18). In that scenario, the DECT PABXs are connected to a GSM MSC using the DSS1+ ISDN interface. Traffic is carried by the GSM network, and inter-PABX mobility is provided by the GSM HLR/VLR. The terminal is a GIP-compliant DECT portable.

In an equivalent scenario, we have the same functions as in Figure 8.18, but a DECT FP is connected to the MSC by the A-interface. Local mobility is provided by the DECT system. Wide-area mobility is provided by the GSM HLR/VLR, and the terminal is again a GIP-compliant portable. This scenario also can be extended with a dual-mode terminal, so that when "on site" the call is made via a DECT FP (the wireless PABX), and when "off site" via GSM. Such a service might use existing public pedestrian service sites (e.g., in

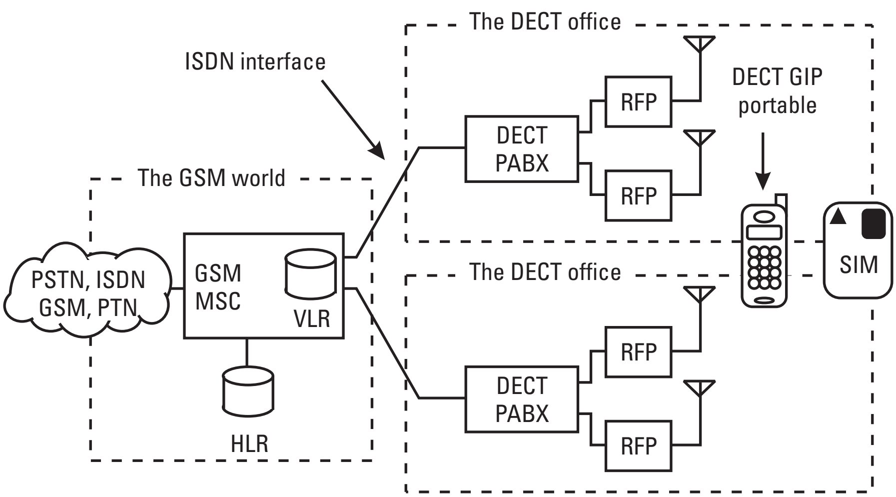


**Figure 8.18** DECT/DECT private networking via GSM. *Source:* ETSI [30].

shopping centers and metropolitan train stations), but subscribers would have incoming call capability and mobility.

In a more advanced scenario (Figure 8.19), a roaming agreement exists between a GSM operator and DECT system owners. The DECT system may be a single FP/RFP (e.g., a residential system) or a wireless PABX with multiple RFPs (e.g., an office environment). The user has a DECT or GSM subscription with either party and can roam seamlessly between the GSM network and the DECT system. The terminal is a dual-mode GSM mobile and GIP-compliant DECT portable. A SIM or a DAM is used, depending on whether the subscription is with a DECT or GSM operator.

## 8.10 Public and Public/Private Applications

The DECT/PWT system as a whole does not really distinguish between public and private applications. However, a number of things are specified to

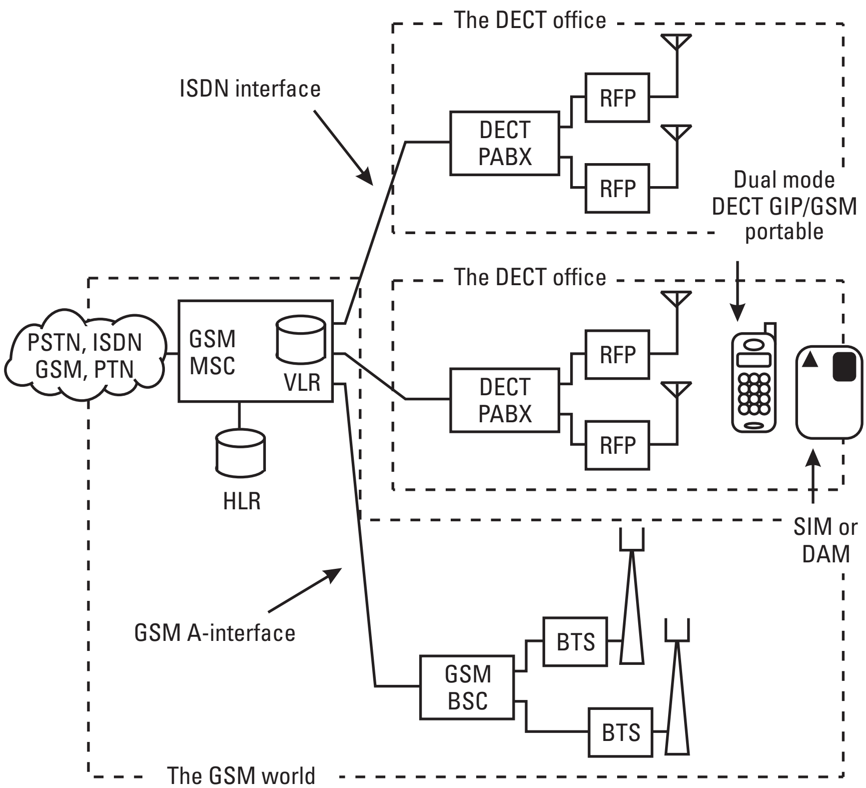


**Figure 8.19** DECT/DECT public/private interworking via GSM. *Source:* ETSI [30].

make public systems viable and the integration of public and private systems possible.

### 8.10.1 Public Access Systems

Providing access to a public cordless infrastructure is much the same, technically at least, as providing access to a private system. The concept, sometimes called telepoint, is that of providing, in effect, a universal public telephone booth, for which the users all have their own handsets. That sounds attractive if handset ownership gets to be common, since the operator no longer has to maintain equipment that is accessible to the public and subject to misuse and other related problems.

The commercial problem that has been seen in the past with such services is that they have never been deployed with continuous coverage because of the cost of acquiring and equipping many small cells. Hence, the ubiquity and falling cost to subscribers of cellular radio access means that not many public telepoint systems are still in operation.

The critical technical matter for public access is that of authentication for the purposes of billing. The procedures built into the air interface for challenge-response authentication (and encryption for privacy) take care of that. However, what the standards do not cover is the key-handling and key-distribution system. As with all secure systems, the technically exciting bit in the center that does the authentication or encryption is not the most critical part.

It used to be thought that authentication and encryption were issues for public applications only, but increasingly the security of private PABXs is being compromised by persistent and technically adept hackers. Thus, the security features of public systems, already built into the DECT system, are being increasingly applied to private applications.

### 8.10.2 Integration of Public and Private System Access

A possibly more attractive use of public access cordless systems is to allow seamless roaming between public and private infrastructure, called cordless terminal mobility or CTM in the European standards arena.

The purpose of CTM is to enable users of cordless terminals to make and receive calls from any location within any public or private telecommunication network where coverage is provided. It is intended that it should be possible to add CTM functionality to those parts of a private telecommunications network where it is required without modification to any other part of the network.

Mobility functions are confined to two places for a given cordless terminal (Figure 8.20):

- The home area, which comprises the HLR within the cordless exchange that controls the home private telecommunication network;
- The currently visited area, which comprises the VLR within the exchange that controls the visited network and the part of the radio system in the vicinity of the portable.

In providing cordless terminal mobility, it was a goal that no changes should be necessary in any part of the private telecommunications network not involved in providing mobility.

A roaming cordless terminal is associated temporarily with an access identity at the network it is currently visiting, which persists while it is registered there. Knowledge of the visited area is sent to the cordless terminal's HLR at the time of its first location registration at the visited network. The access identity to be used is stored in the VLR in the visited area and is updated locally when the access details change (such as roaming within the visited network).

Each cordless terminal is permanently associated with its home network as if it were a terminal attached to that network. Thus, the cordless terminal can be made an addressable entity by assigning a telephone number to it from the

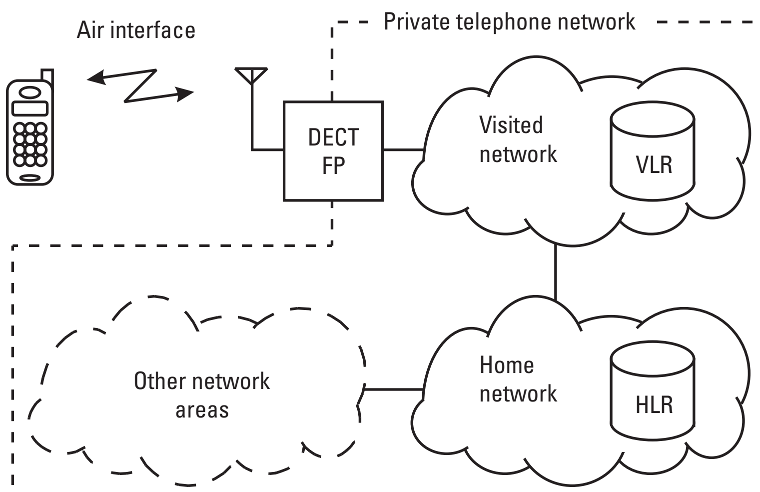


**Figure 8.20** The system model for providing CTM.

number range at the home network, which allows every other connected network to route calls to that cordless terminal.

To accommodate certain implementation scenarios, it is possible to assign to a terminal an identifier that is permanent but not a telephone number on its home network. Such a facility would be used with cordless terminals that are unable to support user-assigned identifiers or in situations where interworking with other (public) networks is a requirement. The identifier is used to determine the CTM user's entry in the HLR and has a one-to-one relationship with the telephone number that is used for routing purposes.

Note that this does not prevent scenarios where the same number can be assigned to a user's cordless terminal and fixed terminal at the same time. The home network can take a local decision which of the two is to receive an incoming call or it can decide to ring at both terminals in parallel.

The DECT standard that specifies the set of technical requirements for FPs and PPs necessary for the support of CTM is the CAP [31], which is an extension of the GAP, specifying only those components not mandatory in the GAP that are needed in the CTM context. It supports telephony teleservice and provides a 32-kbps ADPCM speech bearer service. The concepts of the CAP are similar to those covered by the use of the GSM network as the provider of mobility services for multiple public and private cordless systems (see Section 8.9.5 and Figure 8.20).

## References


1. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI)*, ETS 300 175 (9 parts), Sophia Antipolis, France, September 1996.

2. TIA/EIA, *Personal Wireless Telecommunications Interoperability Standard (PWT)*, 13 parts, TIA/EIA 662-1997.

3. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Generic Access Profile (GAP),* EN 300 444, Sophia Antipolis, France, August 1997.

4. TIA/EIA, *Personal Wireless Telecommunications Interoperability Standard (PWT); Part 9: Customer Premises Access Profile (CPAP)*, TIA/EIA 662-9-1997.

5. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 8: Speech Coding and Transmission,* ETS 300 175-8, Sophia Antipolis, France, September 1996.

6. ETSI, *DECT/ISDN Interworking for End System Configuration; Part 1: Interworking Specification,* ETS 300 434-1, Sophia Antipolis, France, April 1996.

7. ETSI, *Draft DECT/ISDN Interworking for Intermediate System Configuration; Interworking and Profile Specification,* ETS 300 822, Sophia Antipolis, France, January 1998.

8. ETSI, *Integrated Services Digital Network (ISDN); Digital Subscriber Signalling System No. 1 (DSS1) protocol and Signalling System No. 7 Protocol; Signalling Application for the Alpha Interface of Cordless Terminal Mobility (CTM)*, DE/SPS-05121, Sophia Antipolis, France, 1998.

9. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL),* ETS 300 175-2, Sophia Antipolis, France, September 1996.

10. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 6: Identities and Addressing,* ETS 300 175-6, Sophia Antipolis, France, September 1996, with Amendment 1 of August 1997.

11. ITU-T Recommendation G.821: *Error Performance of an International Digital Connection Operating at a Bit Rate Below the Primary Rate and Forming Part of an Integrated Services Digital Network*, Geneva, 1996.

12. ETSI, *DECT Data Services Profile (DSP); Profile Overview,* ETR 185, Sophia Antipolis, France, December 1995.

13. ETSI, *A High Level Guide to the DECT Standardisation,* ETR 178, Sophia Antipolis, France, January 1997.

14. ETSI, *DECT Data Services Profile (DSP); Base Standard Including Interworking to Connectionless Networks (Service Types A and B, Class 1),* ETS 300 435, Sophia Antipolis, France, February 1996.

15. ETSI, *DECT Data Services Profile (DSP); Generic Frame Relay Service With Mobility (Service Types A and B, Class 2),* ETS 300 701, Sophia Antipolis, France, October 1996.

16. ETSI, *DECT Data Services Profile (DSP); Generic Data Link Service for Closed User Groups (Service Type C, Class 1),* ETS 300 699, Sophia Antipolis, France, October 1996.

17. ETSI, *DECT Data Services Profile (DSP); Generic Data Link Service; Service Type C, Class 2,* ETS 300 651, Sophia Antipolis, France, September 1996.

18. ETSI, *Draft Digital Enhanced Cordless Telecommunications (DECT); Data Services Profile (DSP); Point-to-Point Protocol (PPP) Interworking for Internet Access and General Multi-Protocol Datagram Transport,* EN 301 240, Sophia Antipolis, France, August 1997.

19. ETSI, *DECT Data Services Profile (DSP); Multimedia Messaging Service (MMS) With Specific Provision for Facsimile Services; (Service Type F, Class 2),* ETS 300 755, Sophia Antipolis, France, May 1997.

20. ETSI, *DECT Data Services Profile (DSP); Low Rate Messaging Service; (Service Type E, Class 2),* ETS 300 757, Sophia Antipolis, France, April 1997.

21. ETSI, *DECT/GSM Interworking Profile (IWP); Implementation of Short Message Service, Point-to-Point and Cell Broadcast,* ETS 300 764, Sophia Antipolis, France, May 1997.

22. ETSI, *Draft Digital Enhanced Cordless Telecommunications (DECT); Data Services Profile (DSP); Isochronous Data Bearer Services With Roaming Mobility (Service Type D, Mobility Class 2),* EN 301 238, Sophia Antipolis, France, August 1997.

23. ETSI, *Draft Digital Enhanced Cordless Telecommunications (DECT); Data Services Profile (DSP); Isochronous Data Bearer Services for Closed User Groups (Service Type D, Mobility Class 1),* EN 301 239, Sophia Antipolis, France, August 1997.

24. ETSI, *DECT Services, Facilities and Configurations for DECT in the Local Loop,* ETR 308, Sophia Antipolis, France, August 1996.

25. ETSI, *DECT Radio in the Local Loop (RLL) Access Profile (RAP); Part 1: Basic Telephony Services,* ETS 300 765-1, Sophia Antipolis, France, August 1997.

26. ETSI, *DECT Radio in the Local Loop (RLL) Access Profile (RAP); Part 2: Advanced Telephony Services,* ETS 300 765-2, Sophia Antipolis, France, January 1997.

27. ETSI, *Application of DECT Wireless Relay Stations (WRS),* ETR 246, Sophia Antipolis, France, November 1995.

28. ETSI, *DECT Wireless Relay Station (WRS),* ETS 300 700, Sophia Antipolis, France, March 1997.

29. ETSI, *DECT General Terminal Attachment Requirements: Telephony Applications,* TBR 010, Sophia Antipolis, France, January 1997.

30. ETSI, *DECT/GSM Interworking Profile (IWP); Profile Overview,* ETR 341, Sophia Antipolis, France, December 1996.

31. ETSI, *Digital Enhanced Cordless Telecommunications (DECT); Cordless Terminal Mobility (CTM); CTM Access Profile (CAP),* ETS 300 824, Sophia Antipolis, France, October 1997.