

corDECT

Wireless Access System

December 2000

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Abbreviations

corDECT is an advanced, field proven, Wireless Access System developed by Midas Communication Technologies and the Indian Institute of Technology, Madras, in association with Analog Devices Inc., USA.

corDECT provides a complete wireless access solution for new and expanding telecommunication networks with seamless integration of both voice and Internet services. It is the only cost-effective Wireless Local Loop (WLL) system in the world today that provides simultaneous toll-quality voice and 35 or 70 kbps Internet access to wireless subscribers.

corDECT is based on the DECT standard specification from the European Telecommunication Standards Institute (ETSI). In addition, it incorporates new concepts and innovative designs brought about by the collaboration of a leading R & D company, a renowned university, and a global semiconductor manufacturer. This alliance has resulted in many breakthrough concepts including that of an Access Network that segregates voice and Internet traffic and delivers each, in the most efficient manner, to the telephone network and the Internet respectively, without the one choking the other. Chapter 2 discusses this.

Chapter 3 contains a brief description of the various corDECT sub-systems that make it scalable and modular. Next, Chapter 4 describes the several ways in which corDECT can be deployed to cater to a wide variety of subscriber densities and teletraffic levels, to suit both incumbent and greenfield operators.

Chapter 5 presents at a glance the key features and services provided by the corDECT system. The topic of Chapter 6 is the dimensioning of the corDECT system to cater to the required voice and Internet traffic levels. Chapter 7 highlights the coverage achieved by different configurations.

A system with active elements at each subscriber location, apart from several Base Station sites, requires a sophisticated and user-friendly Network Management System (NMS) for monitoring and maintenance. Chapter 8 discusses the NMS available for corDECT. Chapter 9 gives a glimpse of the future, as corDECT evolves to a full-fledged 3G+ system with advanced features such as fast download from the Internet.

Finally, there is an Appendix that gives a brief overview of the DECT standard. The main aspects of DECT are dealt with here, in particular MC-TDMA medium-access and Dynamic Channel Selection. A short list of key DECT physical parameters is also included.

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Chapter 2 Wireless Access Network: Some Key Issues

2.1 Introduction

Till around the mid-eighties, a local loop or an Access Network (AN) used to consist of a pair of copper wires connecting the subscriber at home or office to the nearest exchange. The local loop length in urban areas would be typically as long as 6 to 8 km and the diameter of the copper used was 0.5 mm to 0.6 mm. The loop was designed to carry 0 - 4 kHz voice and was difficult to maintain, with almost 85% of all faults found in the local loop. Above all it was expensive, as well as difficult and time-consuming, to deploy. With copper and digging costs increasing every year, if one were to continue with such an approach, the per-line local loop cost itself would today amount to over 80% of the total cost of putting up a telecom network.

2.2 Access Network

Fortunately, an uncelebrated but major technological innovation changed the Access Network from the mid-eighties onwards. As

shown in Figure 2.1, the AN now consists of an optical fibre from an exchange to a Remote Line Unit (RLU) and typically a 3 - 4 km copper loop from the RLU to the subscriber premises. The signals carried on the fibre are time-multiplexed digital voice and signaling information. A RLU typically serves 1000 to 4000 subscribers and the links from RLU to exchange consist of 4 - 16 E1's. Since the loop length is reduced to 3 - 4 km, a wire gauge of 0.4 mm is sufficient and this brings down the cost considerably. The rising cost of copper, however, continues to push up the cost of even this solution every year. Today, the per-line copper cost (3 - 4 km long, including laying charges) and the shared cost of fibre and RLU, again amounts to almost two-thirds of the total per-line cost.

The signaling protocol on the AN (in the signaling slots on the E1 links between the RLU's and exchange) initially remained proprietary. However, access signaling was standardized internationally in the early nineties, in the form of the V5.1 and V5.2 protocols. The V5.2 interface makes the

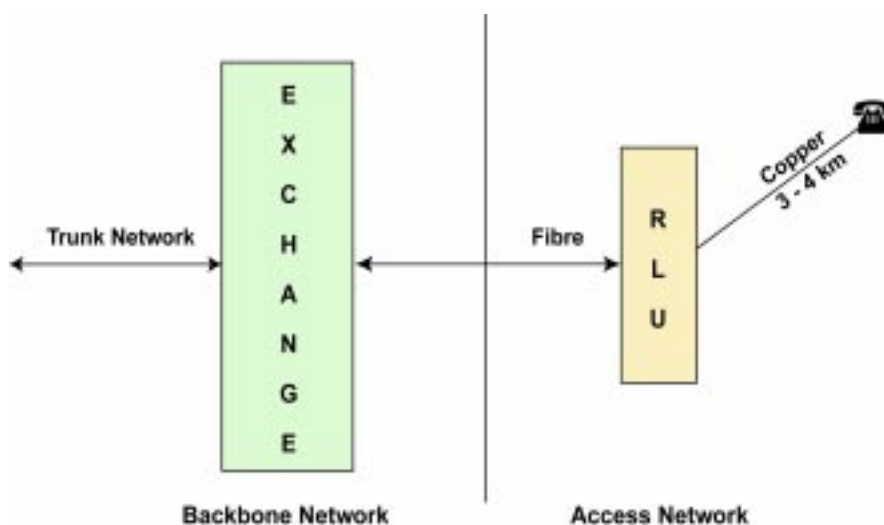


Figure 2.1 Access Network in the 90's

AN appear as an RLU to *any* exchange, overcoming the earlier restriction of having a proprietary RLU for each exchange.

Telephone traffic is concentrated at the AN-exchange interface and one channel is not required for every subscriber line. The dimensioning of the links from the AN to the exchange is determined by an estimate of the traffic. For example, 1000 subscribers with an estimated traffic of 0.1 E per subscriber require no more than four E1 links (120 channels) to the exchange at 0.5% GOS (Grade of Service). This not only implies savings in bandwidth, but also implies that only four E1 interfaces are required at the exchange (as compared to the 1000 two-wire interfaces that would have been required if all 1000 lines were brought to the exchange), thus reducing the cost.

The open V5.2 interface permits the AN to be procured and deployed independently of the exchange vendor. The AN can use innovative technologies on media like fibre, wireless, Digital Subscriber Line (DSL) on copper, hybrid fibre-coaxial cable, or even power-lines. As the AN dominates the cost, is the most fault-prone, and is the most time consuming to deploy, availability of new access solutions is becoming the key to cost-effective expansion of the telecom network. Wireless AN's, just like any other access network of today, must connect to an exchange using the V5.2 access protocol.

Even as the issue involving interface to the telecom network was resolved, another important issue cropped up about three years ago. Today a telecom network can no longer just focus on providing telephone service at homes and offices, but must provide Internet service too. We now examine some of the factors involved in providing Internet connections using the existing telephone network.

2.3 The Internet Tangle

The Internet has emerged as second only to the telephone in connecting people and may tomorrow subsume the telephone network. But today, Internet access at homes and offices largely rides on the telephone network. Internet access appears to be simple: just get a telephone line, connect a modem and computer and dial an Internet Service Provider (ISP). The ISP has a bunch of telephone lines and an equal number of modems connecting the users to a router as shown in Figure 2.2. This router is connected to other routers on the Internet. A dial-up connection to an ISP's router gives a user access to everyone and everything on the Internet.

This straightforward-looking approach to accessing the Internet, is however, beset with problems. The telephone network is typically designed to handle 0.1 E traffic per subscriber on the average. This is generally adequate for voice telephony. However, Internet sessions are

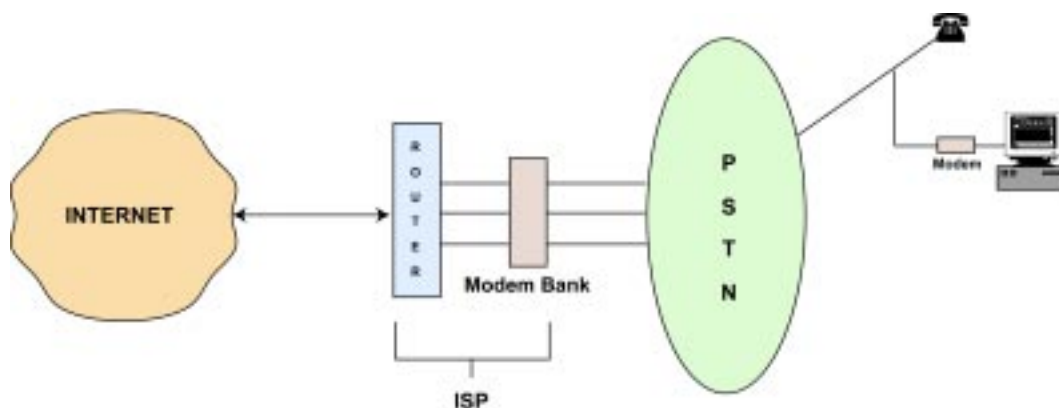


Figure 2.2 Internet access using the telephone network

usually of longer duration, often even exceeding an hour. As a significant percentage of telephone users start accessing the Internet, the load on the telecom network will far exceed 0.1 E per subscriber, resulting in severe congestion and eventual network collapse. If this has not happened yet, it is because only a small percentage of telephone users are also accessing the Internet.

The second problem is associated with the local call charges for accessing the Internet in this manner. In many countries the telephone call made for accessing the Internet is usually charged based on the call duration. In addition, a subscriber may also have to pay the ISP for connection to the Internet.

Thirdly, the analog modem-to-modem link between the subscriber and the ISP is often unreliable. One does not always get connected at 33.6 kbps and the speed can go down to 9.6 kbps and even 4.8 kbps at times, especially in rural areas. Further, the connection often drops. Finally, an ISP with N telephone lines, N modems and a N-port router could serve at most N subscribers at a time. If the connection drops, one may not get an immediate reconnection during busy hours.

This Internet tangle requires a new approach in order to support future growth. Though an Internet connection is kept on for long hours, a peculiarity

of computer-to-computer communications is that the connection is not in continuous use, but in bursts. Packets are transmitted to and from the Internet in bursts, with the link remaining practically idle most of the time. A circuit-switched connection on a telephone network, however, is unable to take advantage of this and dedicates network resources throughout the duration of the connection thereby congesting the network.

An ideal solution to this problem is to have packet-switched access. However, the local loop is often a separate physical line to each subscriber and packet access on this dedicated line gives little advantage, as no one else can use this resource anyway. In such a situation, it is advisable to separate the Internet data at the network node nearest to the subscriber, where data from multiple subscribers can be multiplexed. This is shown in Figure 2.3, where separation of Internet data and voice traffic takes place at the Access Centre (AC), located typically at a street-corner.

As shown in the figure, both wired and wireless interfaces to the AC are possible. DSL technology and narrowband ISDN equipment can provide reliable, high-speed, simultaneous, voice and Internet access on a single copper pair. If wired access is used, there is strictly no restriction on the bitrate between the subscriber and the AC, as long as the physical medium can support it.

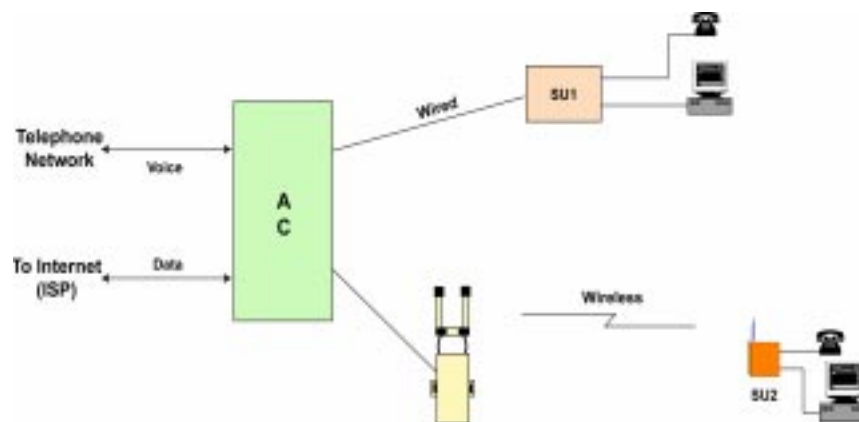


Figure 2.3 Access Centre (AC) separates voice and Internet data; SU1 and SU2 provide simultaneous voice and Internet services to subscribers using wired and wireless connectivity respectively

However, wireless access makes use of an important shared resource, namely, the frequency spectrum. It is this resource which limits the capacity of a wireless system. Thus, access strategies which assign a channel to a subscriber only when he/she wishes to transmit a packet would significantly enhance capacity for Internet access. Wireless access networks which can share the frequency spectrum and utilize it efficiently during packet bursts are obviously very attractive candidates for rapid expansion of Internet access in the future.

2.4 Wireless Local Loop Vs. Mobile Wireless Access System

Today, there is little doubt that wireless access systems should provide digital and not analog access. Wireless connectivity to subscribers today is provided by mobile communication systems as well as wireless local loop systems.

These two appear to be similar and are often confused with each other. However, the requirements for the two systems are significantly different.

2.4.1 Mobile Telephone System

Mobile telephone systems, often called “cellular” systems, are meant to provide telephony for people on the move. The handset is primarily meant to keep the subscriber connected while he/she is away from the home or office. The key here is total coverage of the city/state/country. The mobile telephone must be reachable wherever the subscriber is — in the car, on the street, or in a shopping mall. Other requirements are secondary. Modest voice quality is acceptable as the user may often be speaking from a location with high ambient noise, such as a street or a car. Data communication is not very important. Fax communication is highly unlikely to be used.

Internet access will be provided on the next-generation systems. The important applications

will normally be email and web browsing with small displays. The data rate needed is much less than for accessing the Internet from a desktop PC. Finally, the traffic per subscriber will not be high: typically, it will be only 0.02 E traffic per subscriber. Additional air-time charges for such value-added services are generally acceptable to users.

2.4.2 Wireless Local Loop System

A Wireless Local Loop (WLL) system, on the other hand, is meant to serve subscribers at homes or offices. The telephone provided must be at least as good as a wired phone. Voice quality must be good — a subscriber carrying on a long conversation must feel comfortable. One must be able to use speakerphones, cordless phones and parallel phones. The telephone must support fax and modem communications and should be usable as a Public Call Office (PCO). The ability to support at least medium-speed (about 64 kbps) Internet access is a must. Further, the traffic supported should be reasonably high — at least 0.1 E per subscriber. Besides, the ability to support a large number of subscribers in an urban area (high teledensity) with a limited frequency spectrum is required. Finally, for the system to be viable, the cost of providing this wireless access should be less than that of a wired telephone connection. Air-time charges are totally unacceptable.

Therefore, even though mobile communication systems and WLL systems appear to be similar and are sometimes even referred to interchangeably, the requirements in the two applications are quite distinct.

2.5 Capacity and Spectral Efficiency

Having looked at the PSTN-AN interface and the requirements that a WLL system has to fulfill, let us now take up the most important issue that governs the choice of a WLL technology. One

has to recognize that the frequency spectrum available will always be limited. Since a telephone or an Internet connection is not used continuously, channels must obviously be assigned to a subscriber on demand. But this is not enough. The key focus has to be efficient use and spatial re-use of the spectrum.

What governs the re-use of spectrum? The use and re-use of spectrum is governed by multiple factors including:

- i. channel pay load (bitrate)
- ii. signaling overhead
- iii. modulation efficiency
- iv. cell radius (range)
- v. multiple access method
- vi. interference reduction techniques
- vii. spatial diversity and space-time processing

i. Channel Pay Load

It is obvious that a higher payload will require more frequency resources. Therefore, for voice communication on wireless systems, it may be desirable to have efficient voice compression and lower bitrate voice codecs. The resulting reduction in quality, however small, is quite acceptable for mobile communications. But for telephones at homes and offices, toll-quality voice communications at 32 kbps/64 kbps (ADPCM/PCM) is desirable. Besides, PCM and ADPCM are transparent to other communication services like fax. For Internet access, high bitrate communication is obviously desirable. As the frequency resource used per channel is directly proportional to the payload, high bitrate Internet access implies use of more frequency resources.

ii. Signaling Overhead

As signaling is the key to the setting up, monitoring, and tearing down of a call, it needs

to be carried out on air between the subscriber equipment and the Base Station. Signaling is an overhead that takes away part of the frequency resources but plays an important role in improving the overall efficiency of spectrum usage.

iii. Modulation Efficiency

The modulation technique employed has a direct bearing on the efficient use of spectrum. Highly spectrum-efficient techniques have been developed over the years. For example, 16-QAM is more spectrally efficient than 8-QAM, which in itself is more efficient than QPSK and MSK modulation techniques. But more efficient techniques are usually expensive to implement and may sometimes require larger power margins. For a WLL system, cost is an important consideration and the power margin available is usually not large. QPSK, MSK or even BFSK techniques are often used, even though their spectral efficiency is modest.

iv. Cell Radius

Cell radius is perhaps the most important factor governing spectrum utilization in a wireless system. Let there be N independent channels available for use in a cell of radius r . It is the re-use efficiency which determines the re-use of channels in neighboring cells. Leaving this issue aside for the moment, let us concentrate on the N channels available within a cell. Let us also assume that the traffic per subscriber is e Erlangs. The number of subscribers that can be served in the cell works out to N/e and the Subscriber Density (SD) that can be served in this cell is approximately,*

$$SD = \frac{N}{e \pi r^2} \text{ subscriber/sq.km}$$

Thus, subscriber density is inversely proportional to the square of the cell radius. The implication of this can be seen by an example. If $N = 200$

* For a large number of servers N , from the Erlang-B formula, at 1% blocking probability, the offered load can be nearly N Erlangs.

and $e = 0.1 E$, the capacity (subscriber density) varies with cell radius as follows:

| r (km) | SD (per sq. km) |
|--------|-----------------|
| 25 | 1 |
| 10 | 6 |
| 3 | 70 |
| 1 | 640 |
| 0.5 | 2550 |

Therefore, cell radius plays the dominant role in determining the subscriber density given a certain amount of frequency spectrum. In other words, a smaller cell radius (microcell) is the key to efficient use of spectrum and one may have to have cells as small as 500 m in radius, if a high subscriber density is desired.

v. Multiple Access Technique

A key parameter determining the efficient re-use of spectrum is the multiple-access technique used. The access technique defines how frequency spectrum is divided into channels and affects re-use. FDMA, TDMA, CDMA, and MC-TDMA are different multi-access techniques which affect the re-use factor (extent to which the spectrum can be re-used in every cell). Re-use further depends on the number of sectors used in a cell and also on whether Fixed Channel Allocation (FCA), or Dynamic Channel Selection (DCS) is used. For CDMA and MC-TDMA, the

re-use factor varies from 0.25 to 0.5 per sector.

vi. Interference Reduction Techniques

The re-use distance is primarily determined by the minimum Signal to Interference Ratio (SIR) requirement. The target SIR is based on the minimum sensitivity required at the receiver input in order to obtain a particular Bit Error Rate (BER). The required BER is typically 10^{-3} for voice applications (and 10^{-6} or lower for data applications, obtained by using error control coding and/or ARQ). Depending on the choice of multiple access technique, the modulation scheme, and the particular application (mobile or fixed wireless), the target SIR will differ.

Interference reduction techniques are widely used in wireless systems to increase re-use efficiency while retaining the target SIR requirement.

2.6 Summary

A Wireless Access System today must provide simultaneous voice and medium-rate (at least) Internet connectivity at homes and offices. To serve dense urban areas, the system should support a microcellular architecture, whereas for rural areas, larger range is desirable. At the Access Unit, the voice and Internet traffic from subscribers should be separated and delivered to the telephone and Internet networks respectively.

3.1 Introduction

The corDECT Wireless Access System (WAS) is designed to provide simultaneous circuit-switched voice and medium-rate Internet connectivity at homes and offices. The Access System model, which the corDECT emulates, is shown in Figure 3.1.

3.2 Conceptual Access System

In this conceptual model, there is a Subscriber Unit (SU) located at the subscriber premises. The SU has a standard two-wire interface to connect a telephone, fax machine, PCO (Public Call Office), speakerphone, cordless phone, or modem. It also provides direct (without a modem) Internet connectivity to a standard PC, using either a serial port (RS-232 or USB) or Ethernet. The Access System allows simultaneous telephone and Internet connectivity. The SU's are connected to an Access Centre (AC) using any convenient technology like wireless, plain old copper, DSL on copper, coaxial cable, optical fibre, or even power lines.

The AC must be scalable, serving as few as 200 subscribers and as many as 2000 subscribers. In urban areas, the AC could be located at a

street corner, serving a radius of 700 m to 1 km. This small radius in urban areas is important for wireless access, in order to enable efficient re-use of spectrum. When cable is used, the small radius ensures low cost and higher bitrate connectivity. However in rural areas, the distance between the AC and the SU could easily be 10 km and even go up to 25 km in certain situations.

The AC is thus a shared system catering to multiple subscribers. The voice and Internet traffic to and from subscribers can be *concentrated* here and then carried on any appropriate backhaul transport network to the telephone and Internet networks respectively.

At the AC, the telephone and Internet traffic is separated. The telephone traffic is carried to the telephone network on E1 links using access protocols such as V5.2. The Internet traffic from multiple subscribers is statistically multiplexed, taking advantage of the bursty nature of Internet traffic, and carried to the Internet network. As use of Voice-over-IP (VoIP) grows, voice traffic from subscriber units could also be sent to the Internet, gradually making connectivity to the telephone network redundant. However, for connecting to the legacy telephone network, the

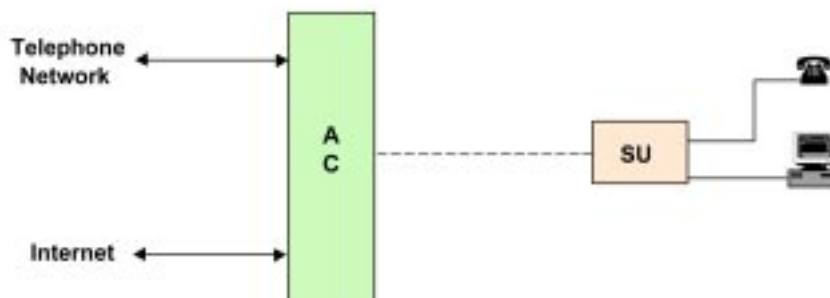


Figure 3.1 Conceptual Access System providing simultaneous voice and Internet connectivity.
SU: Subscriber Unit ; AC: Access Centre

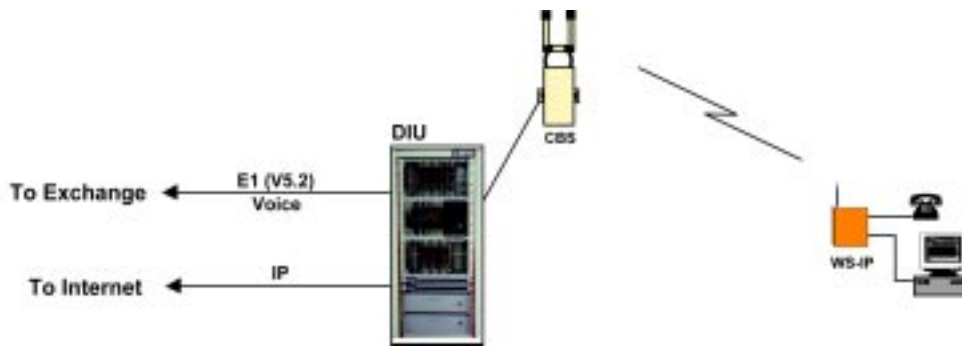


Figure 3.2 corDECT Wireless Local Loop

voice port of the AC may be required for some time to come. An AC could also incorporate switching and maintenance functions when required. Further, it is possible to co-locate Internet servers with the AC.

3.3 corDECT Wireless Access System

Following the conceptual model, the corDECT Wireless Access System uses a similar architecture to provide telephone and Internet service to a subscriber, as shown in Figure 3.2.

The subscriber premises equipment, Wallset IP (WS-IP) or Wallset (WS), has a wireless connection through a Compact Base Station (CBS) to an Access Switch, called a DECT Interface Unit (DIU). The air interface is compliant to the DECT standard specified by ETSI. The DIU switches the voice traffic to the telephone network using the V5.2 protocol to connect to an exchange. The DIU also switches the Internet

calls to a built-in Remote Access Switch (RAS) which then routes the traffic to the Internet network. The RAS has an Ethernet interface, which is connected to the Internet using any suitable routing device.

The CBS is normally connected to the DIU using three twisted-pair wires, which carry signals as well as power from the DIU to the CBS. Alternatively, it can be connected to the DIU through a Base Station Distributor (BSD). The BSD is a remote unit connected to the DIU using a standard E1 interface (on radio, fibre, or copper) as shown in Figure 3.3. A BSD can support up to four CBS's.

For long-range communication, a WS-IP or WS can also be connected to the CBS using a two-hop DECT wireless link, one between WS-IP or WS and a Relay Base Station (RBS) and another between the RBS and CBS, as shown in Figure 3.4. The wireless range supported between a WS-IP or WS and the CBS or RBS is 10 km in Line-

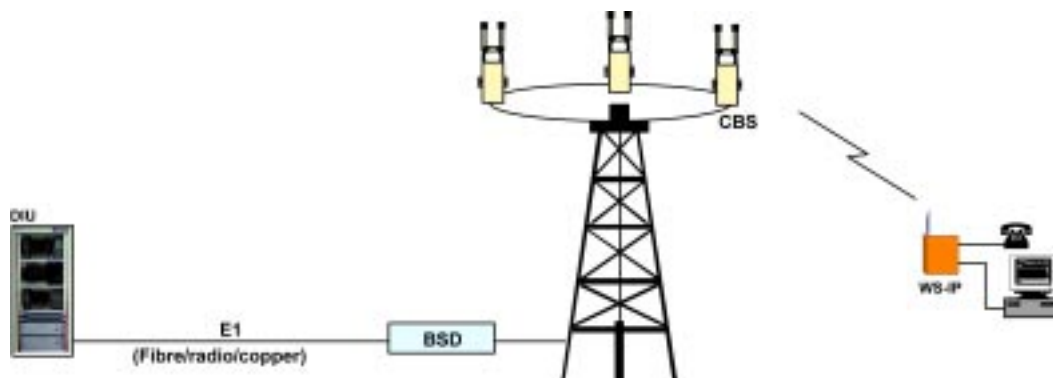


Figure 3.3 CBS remoted to DIU through BSD

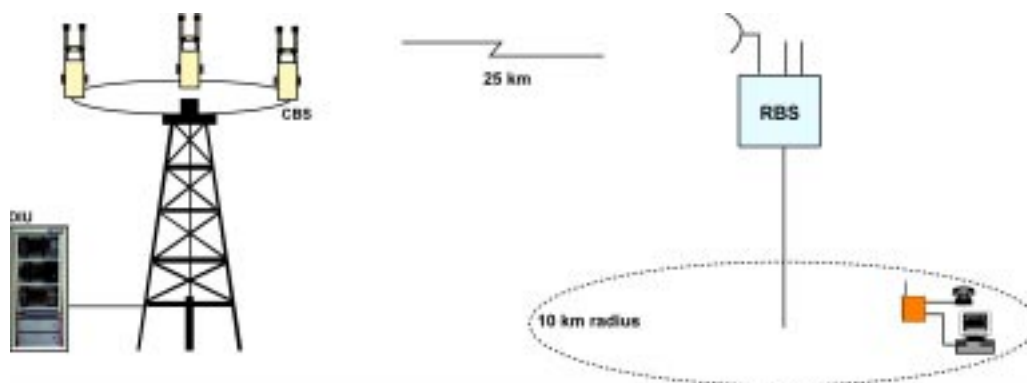


Figure 3.4 WS-IP connected to DIU using a two-hop radio link through a Relay Base Station

of-Sight (LOS) conditions. The range supported between a CBS and RBS is 25 km in LOS conditions.

A typical system consists of one DIU with one or two RAS units, up to 20 CBS's, and up to a 1000 WS-IP's or WS's. The BSD and RBS units are used as required by the deployment scenario.

3.4 Sub-systems of corDECT Wireless Access System

Before we get into more details at the system level, we take a brief look at each of the sub-systems.

3.4.1 Wallset IP and Wallset

As shown in Figure 3.5, the Wallset with Internet Port (WS-IP) provides voice connectivity to the

subscriber using a RJ-11 interface, enabling one to connect a standard DTMF or decadic telephone, G3 fax machine, PCO (battery reversal and 12/16 kHz metering are standard features), speakerphone, cordless phone, or modem. In addition, the WS-IP has a RS-232 port to directly connect a PC (obviating the need for a telephone modem). The PC establishes a dial-up PPP (Point-to-Point Protocol) Internet connection using a standard dial-up utility. Internet access is supported at 35 or 70 kbps. In fact, the WS-IP can support *simultaneous* voice and 35 kbps Internet connections.

Besides these two user interfaces, the WS-IP has an antenna port where either a whip antenna, or an externally mounted antenna (through cable), can be connected. The power to the WS-IP is provided by a 12 V adaptor connected to



Figure 3.5 WS-IP (Wallset with Internet Port)

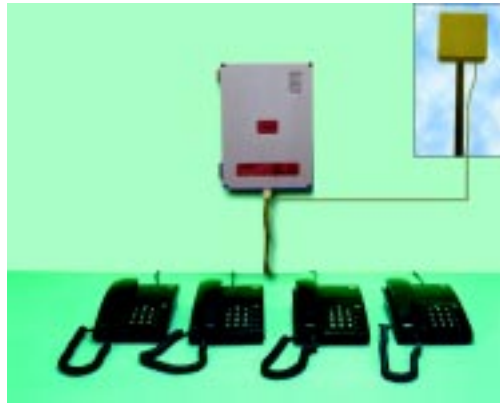


Figure 3.6 Multiwallset

the AC mains and optionally by a solar panel which can be connected in parallel. The WS-IP has a built-in battery and battery charger. The built-in battery provides 16 hours stand-by time and more than 3 hours talk time for voice calls.

A Wallset (WS) is a similar terminal without the Internet port.

3.4.2 Multiwallset

The Multiwallset (MWS), shown in Figure 3.6, provides simultaneous voice service to four subscribers. It has all the features of the WS, but at a significantly lower per-line cost.

The Multiwallset has a DECT Transceiver Module (DTM), which is an outdoor unit with a built-in antenna with 7.5 dB gain. It is connected to an indoor Subscriber Interface Module (SIM) unit, which has four RJ-11 ports for telephones. Each port supports all the terminals a WS supports (see section 3.4.1).

The connection between the DTM and the SIM uses a single twisted-pair wire, obviating the need for RF cable and connectors. The MWS has a built-in battery for backup and is powered through the AC mains.

3.4.3 Multiwallset IP

The Multiwallset with Internet Port (MWS-IP) is a MWS with four telephones and an additional Ethernet interface to provide *dial-up* Internet

connectivity. Multiple PC's can be connected to the Ethernet port and provide a *shared* 35/70 kbps Internet connection. The PPP-over-Ethernet protocol is used to set up individual connections. It is to be noted that at any time, either four simultaneous telephone calls with no Internet connection, or three telephone calls and a 35 kbps shared Internet connection, or two telephone calls and a shared 70 kbps Internet connection, can be made. Depending on usage, this may introduce some blocking for voice calls.

3.4.4 Compact Base Station

The Compact Base Station (CBS), shown in Figure 3.7, provides the radio interface between the DIU and the corDECT subscriber terminal. It supports up to 12 simultaneous voice calls. It is a small, unobtrusive, weatherproof unit that is remotely powered from the DIU or a BSD.

The CBS has two antennas for diversity. A directional antenna with significant gain can be used when coverage is required to be confined to certain directions. For example, if the coverage area is divided into sectors, each sector can be covered by a different Base Station with directional antennas. For 360° coverage using a single CBS, omni-directional antennas are used. More than one CBS can be deployed to serve a single sector or a cell.

The maximum LOS range between a subscriber unit and a CBS is 10 km. An isolated CBS



Figure 3.7 Compact Base Station

supports approximately 5.8 E of traffic with a Grade of Service (GOS) of 1%, typically serving 30 - 70 subscribers. Multiple CBS's serving the same sector or cell increase the traffic in Erlangs handled by each CBS (see Chapter 6).

The CBS is connected to a DIU or a Base Station Distributor (BSD) with three twisted-pair copper wires, each of which carry voice/data traffic, signaling and power. The maximum loop length, with a 0.4 mm diameter wire, can be 4 km between the DIU and the CBS and 1 km between the BSD and the CBS.

3.4.5 DECT Interface Unit

The DECT Interface Unit (DIU) shown in Figure 3.8, implements the functions of a switch (or a

Remote Line Unit), Base Station Controller, and the Operations and Maintenance Console (OMC). System reliability is guaranteed by a redundant, hot stand-by architecture. The OMC allows exhaustive real-time monitoring and management of the entire corDECT system. A fully-configured DIU with an in-built Remote Access Switch (RAS) only occupies a single 28U, 19" cabinet and consumes less than 600 W.

Up to 20 CBS's can be supported by a DIU, directly or through the BSD. The DIU provides up to eight E1 links to the telephone network and/or RAS. The signaling protocol used is either V5.2, which parents the DIU (as an RLU) to an exchange, or R2-MF, in which case the DIU acts as a 1000-line exchange. There is a third option,



Figure 3.8 DECT Interface Unit (DIU) with in-built RAS



Figure 3.9 iKON RAS

wherein the corDECT system, using additional equipment, appears to an exchange simply as a number of twisted-pair lines (see section 3.5.1.2.).

Multiple DIU's are managed through a centralized Network Management System (NMS).

3.4.6 iKON Remote Access Switch

The iKON Remote Access Switch (RAS), shown in Figure 3.9, is a 19" 1U unit normally integrated within the DIU cabinet. It terminates the PPP connections from Internet subscribers using corDECT WS-IP or MWS-IP. It is connected to the DIU using up to two E1 ports and does IP-based routing for up to 60 simultaneous corDECT Internet calls. The RAS has a 10BaseT Ethernet port to connect to the Internet. It supports RADIUS for accounting and authentication, PAP for user authentication and is managed using SNMP.

3.4.7 Base Station Distributor

The Base Station Distributor (BSD) is a compact, remotely located, locally powered, rack-mountable unit that supports up to four CBS's

(with power feed). The E1 interface between a DIU and the BSD can be on copper, fibre, or radio and link distance depends only on the link design.

The BSD is designed to extend corDECT coverage to pockets of subscribers located far away from the DIU.

3.4.8 Relay Base Station

A Relay Base Station (RBS), as shown in Figure 3.11, extends the range of the corDECT system by relaying DECT packets between the CBS and subscriber units. The RBS can handle 11 calls simultaneously.

The RBS consists of two units. The RBS Air Unit is typically mounted on a tower/mast and houses the baseband and the RF sub-system. The RBS Ground Unit supplies power and provides maintenance support to the Air Unit and is mounted at the bottom of the tower.

The RBS uses three antennas. One antenna (usually a directional antenna with high gain), referred to as the RBSWS antenna, points towards the CBS with which the RBS is communicating. The other two antennas, called



Figure 3.10 Base Station Distributor



Figure 3.11 Relay Base Station

RBSBS antennas are used for communication with the subscriber units (two antennas are used for diversity). These antennas are similar to those used by the CBS.

The maximum LOS range between a CBS and a RBS is 25 km, while the maximum LOS range between the RBS and corDECT subscribers is 10 km.

3.4.9 Network Management

corDECT provides comprehensive operation and maintenance through the *corView* OMC console. Its repertoire includes hardware and software configuration, subscriber administration, accounting, fault notification, and traffic

management. Figure 3.12 depicts the *corView* GUI for configuring the DIU. Commands range from a bird's-eye view of the operational status of a network of corDECT systems to probing the internals of an individual Wallset.

This easy-to-use, menu-driven console can be run either locally or remotely. When used remotely, a single *corView* workstation serves as an NMS for a number of corDECT systems. *corView* can also be used with the *CygNet* NMS to provide integrated management of a network of corDECT and other systems.

corView supports the SNMP protocol and can be connected to the corDECT system by any IP network. In the future, *corView* will also support



Figure 3.12 corView 200 GUI for configuring the DIU

TMN/Q3. When used as a switch, detailed billing records are maintained and can be exported to the billing centre via several media.

3.5 corDECT Access Centre Functionality and Interfaces

The corDECT Access Centre, consisting of a DIU and iKON RAS, is designed to provide interfaces to the telephone network and to the Internet.

3.5.1 The Telephone Connection

The telephone connection provided to a corDECT subscriber is a circuit-switched one. The DIU switches the connection to the telephone network. The interface to the telephone network is provided in three different ways:

- i. RLU mode, with V5.2 protocol on E1 interfaces to a parent exchange,
- ii. Transparent mode, with two-wire interface to a parent exchange and
- iii. Switch mode, with R2-MF protocol on E1 interfaces to the telephone network.

3.5.1.1 RLU Mode

The DIU has up to six E1's that can be connected to a parent exchange using V5.2 signaling. The DIU in this case works as a 1000-line Remote Line Unit of the parent exchange, as shown in Figure 3.13. Even calls between two corDECT subscribers belonging to the same DIU are switched by the parent exchange.

The numbering and all subscriber facilities are provided by the exchange and billing too is carried out at the exchange. The DIU does some limited subscriber administration, such as authenticating a subscriber (as per the DECT standard). The DIU console, however, provides management functions for managing corDECT DIU, CBS, RBS, BSD, WS, WS-IP, MWS and MWS-IP, and also carries out wireless traffic monitoring. The management functions can also be carried out centrally for multiple DIU's, as discussed in Chapter 8. The 1000-line DIU in this mode consists of three 6U 19" racks in one cabinet, leaving additional space for up to three RAS units.

3.5.1.2 Transparent Mode

In this mode, the DIU is parented to an exchange using two-wire interfaces. Each subscriber line is mapped to an unique two-wire port on the exchange. Hook status and digits dialed at WS/WS-IP/ MWS are mapped by the DIU to reflect at the corresponding exchange port. All services of the exchange are available to the subscriber. Billing is carried out at the exchange. However, as in the RLU mode (section 3.5.1.1), the DIU carries out subscriber authentication and system management functions.

To provide two-wire interfaces at the DIU, a Concentrating Subscriber Multiplexer (CSMUX) is used. Each CSMUX, housed in one 6U 19" rack, can provide up to 240 two-wire ports (grouped as 2 x 120 two-wire ports). The CSMUX is connected to the DIU typically using two E1

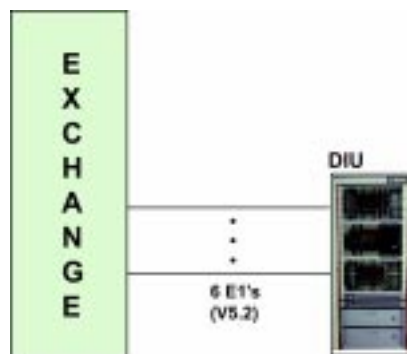


Figure 3.13 DIU parented to an exchange in RLU mode

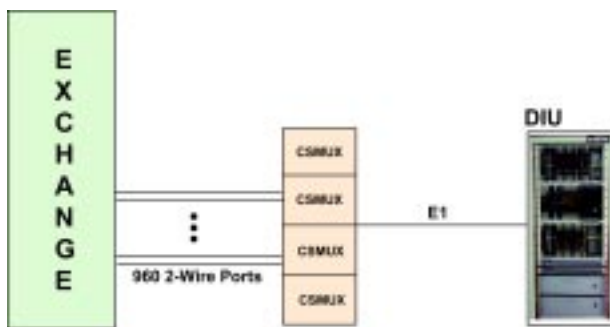


Figure 3.14 DIU parented to exchange in transparent mode

ports, providing 4:1 concentration. Thus, using eight E1's and four CSMUX units and a DIU integrated in two cabinets, one can serve up to 960 subscribers in transparent mode, as shown in Figure 3.14. A concentration of 4:1 is normally acceptable since wireless channels are anyway being shared. Sharing an E1 port among 120 subscribers, one can serve nearly 0.2 Erlang traffic per subscriber at 1% GOS. However, it is possible to avoid concentration at CSMUX and connect eight E1's to a single CSMUX rack. In this case, one DIU will be limited to serve a maximum of 240 subscribers.

The transparent mode is the quickest way to interconnect corDECT to an existing telephone network. However, it is not a preferred mode for operation. In order to serve 960 subscribers, 960 two-wire ports are required on the exchange side connected to four CSMUX units. In contrast, only four to six E1 ports are required at the exchange in the RLU mode and the CSMUX is avoided. Thus, in the RLU mode, the size of the exchange

as well as the DIU is much smaller and the power required is also less when compared to the transparent mode.

A more serious problem in the transparent mode comes from a signaling anomaly that can emerge in some specific situations. For example, when an incoming call comes to the exchange for a subscriber, the exchange signals ring-back to the calling subscriber if it finds from its database that the called subscriber is free. The exchange simultaneously feeds ring to the corresponding two-wire port. This is detected by the CSMUX in the DIU and the DIU then attempts to page the corresponding WS/WS-IP and ring the subscriber. However as wireless channels are shared, it is possible that sometimes the DIU finds no free channel and fails to feed ring to the subscriber. The anomaly develops when the called port gets ring-back tone, but the called party does not get a ring. Such a situation can sometimes become problematic. The transparent mode is therefore not the most desirable mode

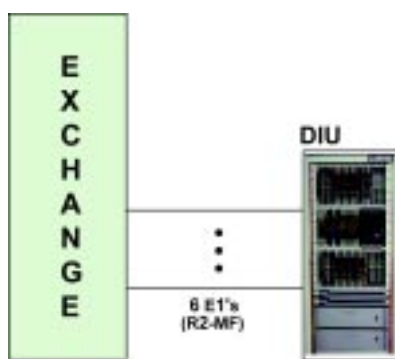


Figure 3.15 DIU as an independent medium-sized exchange

of operation. Nevertheless, it is the quickest way to integrate a wireless system to the existing telephone network anywhere in the world.

3.5.1.3 Switch Mode

The DIU is designed to be a 1000-line, full-fledged, medium-sized exchange for corDECT wireless subscribers. It interfaces to the telephone network on up to six E1 lines using R2-MF protocol as shown in Figure 3.15. All the exchange functions, including subscriber administration, billing, and management, are carried out at the DIU itself. To serve 1000 subscribers in this configuration, a DIU uses three 6U 19" racks. The advantage of this mode is that the cost of an exchange is totally saved.

The DIU can also serve as a Direct In-Dialing (DID) PBX.

3.5.2 Internet Connection

A corDECT subscriber connects to the WS-IP using a PPP dial-up connection on the RS-232 port. The port is programmed at 38.4 kbps rate for a 35 kbps Internet connection and at 115.2 kbps rate for a 70 kbps Internet connection. The PC connected to the RS-232 port on WS-IP dials a pre-designated number using a standard dial-up routine. The DIU sets up a circuit-switched connection between the WS-IP and the iKON RAS connected to the DIU on an E1 port.

The Internet connection employs the wireless link between the WS-IP and the CBS and the wired

links between the CBS and the DIU and between the DIU and the RAS. Since the BER on the wireless link could occasionally be high, the PPP packet is fragmented and transmitted with an error detection code on the link from the WS-IP to the DIU. ARQ is performed on this link to obtain error-free fragment transmission. The PPP packets are re-assembled from these fragments before transmitting it to the PC (on the WS-IP side) and to the RAS (on the DIU side).

The connection between the WS-IP and the DIU is at 32 kbps or 64 kbps (using one or two DECT slots on air). The start/stop bits received at the RS-232 port are stripped before transmission on air. This enables 35 kbps Internet throughput between the user PC and the RAS on the 32 kbps connection in an error-free situation. Similarly, 70 kbps Internet throughput is possible between the user PC and the RAS on the 64 kbps connection. Bit errors on the link will temporarily bring down the throughput.

Each RAS has two E1 ports for connecting to the DIU and thus can support Internet connection for up to 60 subscribers at a time. The PPP connections are terminated at the RAS and IP packets are routed to the Ethernet port of the RAS for onward transmission to the Internet. The Ethernet ports from multiple RAS's would normally be connected to an Ethernet switch. The Ethernet switch in turn would be connected to an Internet router, completing the connection to the Internet.

4.1 Introduction

We saw in Chapter 3 that the corDECT DIU can be deployed as an access system, parented to an exchange using either the V5.2 access protocol, or transparently using two-wire interfaces. Alternatively, the corDECT DIU itself can act as a Local Exchange, or even as a direct-in-dialing PBX. This chapter presents a few deployment scenarios for the corDECT Wireless Access System.

4.2 corDECT Deployment with DIU in Exchange Premises

In one of the most widely deployed scenarios, the corDECT DIU is placed in the local exchange premises, parented to an exchange in a transparent manner or using the V5.2 protocol, or as an independent Local Exchange. This scenario will be widely used by an incumbent operator with existing infrastructure. The exchange building (usually one of the taller buildings in the area) would have a tower to deploy Compact Base Stations as shown in Figure 4.1.

The tower could be a short 15 m rooftop mast, but in some cases, could be a self-supporting 25 - 35 m tower on the ground. Multiple CBS's could be mounted on this tower using omnidirectional antennas, but more often, using directional antennas providing sectorized coverage. A commonly-used sectorization plan provides six-sector coverage as shown in Figure 4.2(a) and Figure 4.2(b). Figure 4.2(c) shows a close up of a CBS and directional antennas.

One or more CBS's are mounted with antennas having a typical gain of 12 dB to provide coverage in a 60° sector. However as discussed in Chapter 6, one or two CBS's with omni directional antennas could be additionally mounted on the same tower, enabling these CBS's to handle overflow traffic from all sectors. All these CBS's are connected to the co-located DIU using twisted-pair cables.

These CBS's provide connectivity to subscribers as far as 10 km away in Line-of-Sight (LOS) conditions. However depending on the built-up environment and in order to re-use the spectrum

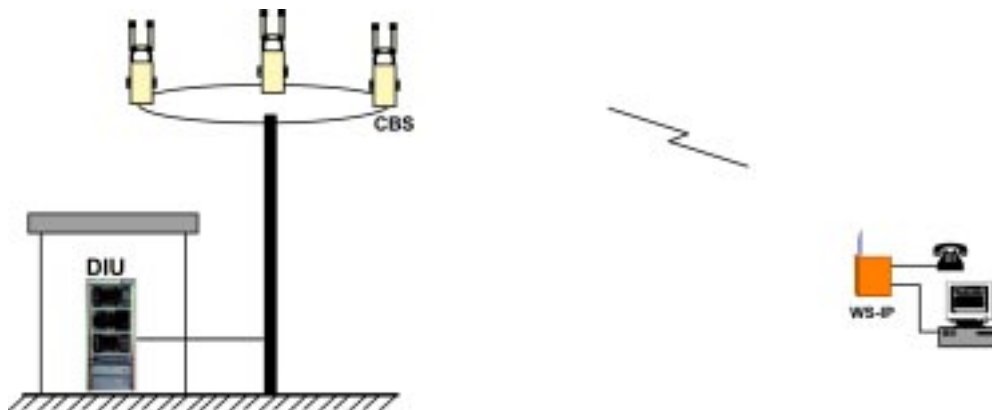


Figure 4.1 DIU in exchange premises with co-located CBS

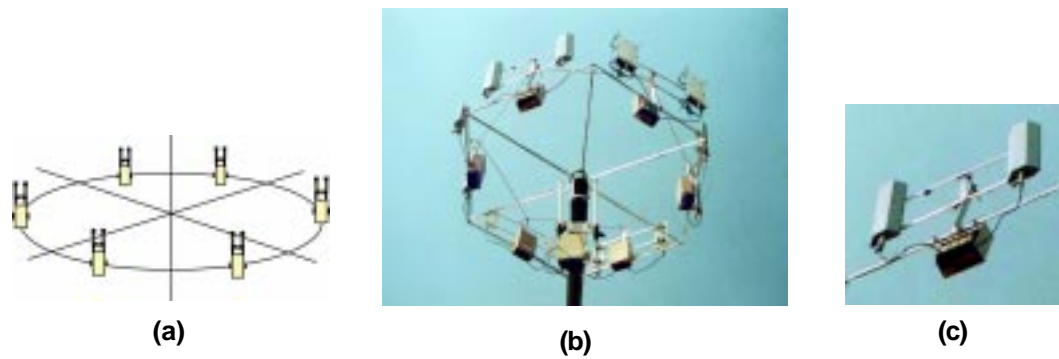


Figure 4.2 Six sector coverage by CBS

more often, coverage should normally be limited to 1 to 1.5 km radius in urban environments (see Chapter 7). Wallsets would typically require an external (rooftop or window-mounted) antenna, but in some cases, within a 400 m radius, an internally-mounted antenna could also be used.

4.2.1 Remote Location of CBS

At times, it may be desirable to cover a distant locality using the same DIU. It is possible to connect a CBS remotely from the DIU using three pairs of twisted-pair wires, which carry the voice, signaling, as well as power, to the CBS. The CBS could be as far as 4 km away, when 0.4 mm diameter copper wire is used. If the buried cable plant in an area is serviceable, it is easy to take three/six/nine pairs of these wires and mount one/two/three CBS's remotely, a few kilometers from the DIU, as shown in Figure 4.3.

The CBS's could then be mounted on a tall building using a 3 - 6 m pole on the roof and

provide coverage to 30 - 150 subscribers in the neighborhood of this remote location. It is important, however, that the buried cable plant be in reasonable shape and not fail during rain, if this option is to be used.

A more appropriate way of connecting a multi-CBS cluster remotely is to use the Base Station Distributor (BSD). A BSD is connected to the DIU by a standard E1 link, using an optical fibre, point-to-point microwave radio, or even copper (for example, using HDSL). The BSD with a small 48 V power supply unit could then be placed in a remote building (say, under a staircase landing) where an optical fibre connection or a cable link with HDSL, is available. Up to four CBS's can now be connected to the BSD and mounted on a pole or small tower on the building as shown in Figure 4.4. These CBS's could provide coverage to almost 200 subscribers in the vicinity.

Alternatively, the tower could also support the antenna for a digital microwave point-to-point E1

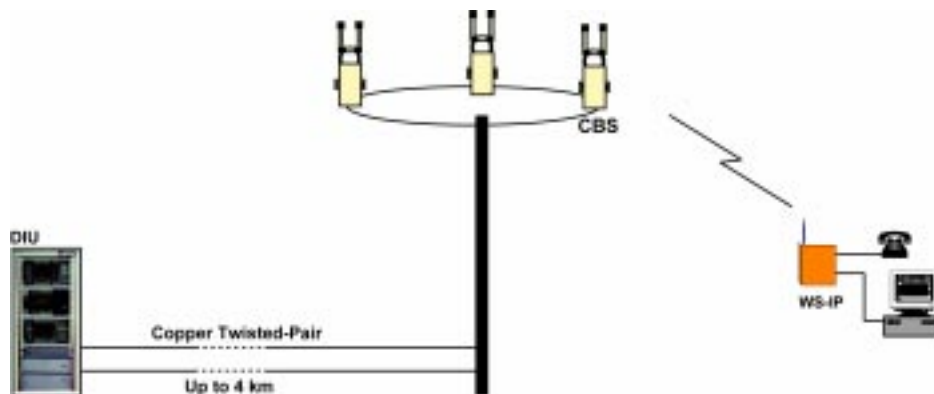


Figure 4.3 Remote CBS connected using copper twisted-pair wire

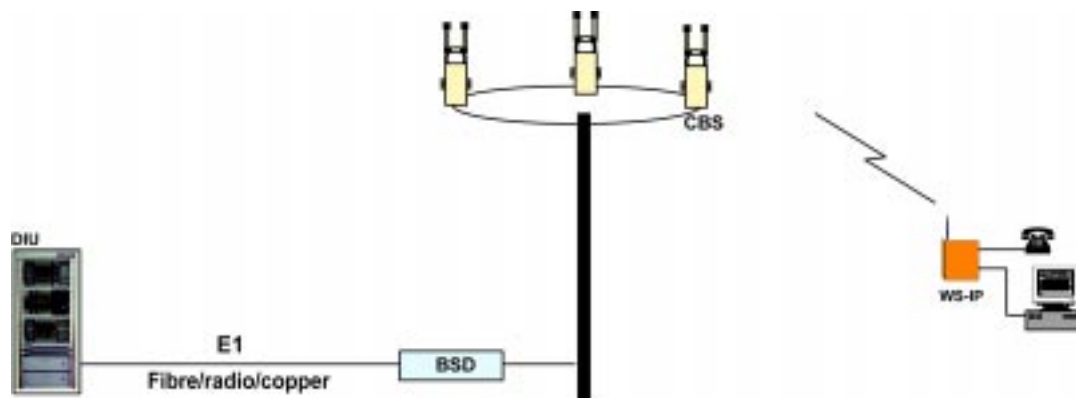


Figure 4.4 Remote CBS deployment using BSD

link from the exchange and the BSD could be connected to it. Again, up to four CBS's could be mounted on this tower and provide service in its neighborhood.

It is to be noted that remoting of Base Stations enables better frequency re-use. The CBS's mounted at the exchange tower and the CBS's mounted remotely can often use the same DECT channels simultaneously.

4.2.2 Internet Connection

An iKON RAS, integrated with the DIU, terminates the PPP connections for all Internet subscribers at WS-IP (see section 3.5.2, Chapter 3). The IP packets are then routed to the Internet by the RAS. The RAS could be connected to the Internet in two different ways. The RAS could be connected to a Local Area Network (LAN), or to a switched LAN, on its 10BaseT Ethernet Interface. A small Internet router (for example,

an Intel 9300 or a CISCO 2610) could be connected to the LAN as shown in Figure 4.5. The Internet router is connected to the Internet using any convenient leased connection. The router could also carry Internet traffic from other access systems.

Alternatively, the traffic between the Internet and RAS could be carried on n x 64 kbps switched (or leased) circuits. This option can be used only if the DIU is connected to the telephone network on E1 lines (using V5.2, or as an independent LE). The circuits are established between the DIU and a remote router using the telephone network. The RAS traffic (IP packets) could then be routed on such a connection through the DIU, as shown in Figure 4.6. Since the RAS is connected to the DIU on E1 lines, a few 64 kbps slots could be used for this. The maximum number of subscriber connections that a RAS (with two E1's) could then support would be less than 60.

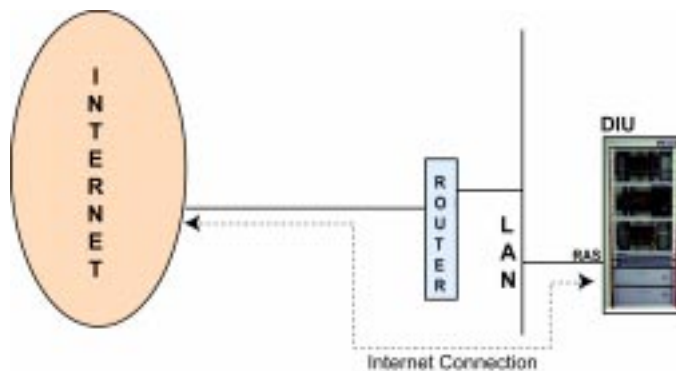


Figure 4.5 Internet connection using a local router at the exchange

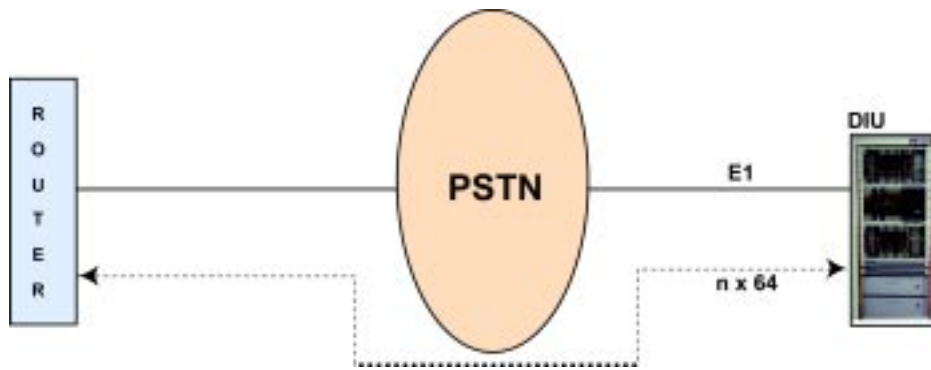


Figure 4.6 n x 64 kbps Internet connection between RAS and remote router

In certain situations, it is possible to locate the RAS remotely, using E1 links to the DIU. This is useful if an operator wishes to install all Internet-related equipment at one place and optical fibre is available between different exchanges and the ISP location. While the DIU's could be located at different exchanges, all the RAS's connected to various DIU's could be at one place along with the routers, servers, and other equipment used by the Internet Service Provider.

The advantage accruing from the RAS statistically multiplexing bursty traffic from different subscribers is not availed here. This may not pose a constraint as fibre typically provides sufficient bandwidth between exchanges at marginal cost. Figure 4.7 shows this scenario.

4.3 DIU Integrated with Access Centre

In an alternative deployment scenario, an Access Centre (AC) is deployed to provide the last-mile connectivity to the subscriber. The AC is deployed away from the exchange and near the subscribers.

The DIU along with the RAS acts as an AC, providing wireless telephone and Internet services to the subscribers. It could also be integrated with other similar access equipment using DSL on copper, cable modem, or even plain old analog telephony on copper to provide service to subscribers in the vicinity. In a typical deployment, the DIU and RAS would be placed at a street

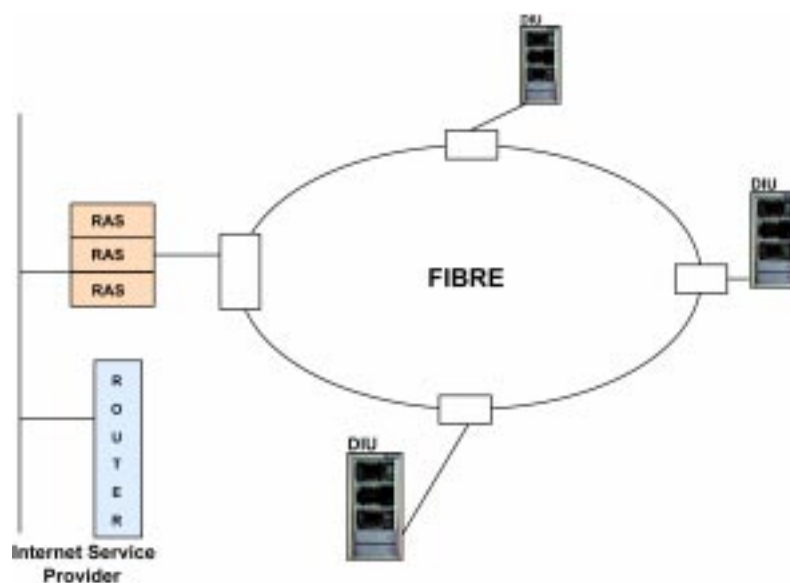


Figure 4.7 Co-location of RAS's

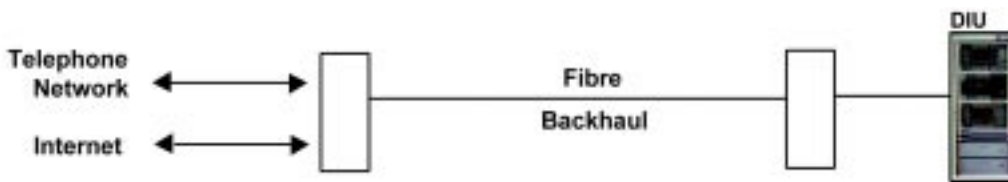


Figure 4.8(a) Fibre backhaul carrying voice and Internet traffic

corner to serve urban subscribers in a 1 to 2 km radius, or placed in the centre of a small town to serve subscribers in a 10 km radius.

The voice and Internet traffic are separated at the DIU and the voice traffic is carried on E1 lines to an exchange using the V5.2 access protocol (the DIU acting as a RLU). The Internet traffic is statistically multiplexed at RAS and carried on E1 lines to the Internet network. Both these connections are provided using a backhaul network built using optical fibre or point-to-point microwave links, as shown in Figures 4.8(a) and 4.8(b) respectively.

It is possible for the Access Centre to extend its reach by remoting some Base Stations using either twisted-pair wires or using the BSD, just as described in section 4.2.1. This approach, while increasing the subscriber reach of the AC, also enables better re-use of frequency spectrum by creating more CBS sites.

4.4 Rural Deployment

Providing telecom and Internet service to subscribers in rural areas is a major application

of the corDECT Wireless Access System. It can cost-effectively provide this service to areas where subscriber density is as low as 0.2 subscribers per sq. km. For a subscriber density lower than this, corDECT may not be the most cost-effective system.

Line-of-Sight (LOS) between a subscriber antenna and Base Station/Relay Base Station is necessary for the corDECT system to provide service to subscribers in sparse (low subscriber density) areas. It is therefore necessary to choose sites for CBS and RBS towers carefully, so that subscribers in a 10 km radius can be provided service. Similarly, antennas have to be mounted at subscriber premises using poles, so that LOS to CBS/RBS is available. The availability of light and compact antennas for the Wallset makes this task somewhat easier.

Further, subscribers in rural areas may not have reliable power and solar panels may have to be used. A compact solar panel can be connected to the WS or WS-IP to power the unit and charge the built-in battery, with solar power taking over when the mains is off/low.

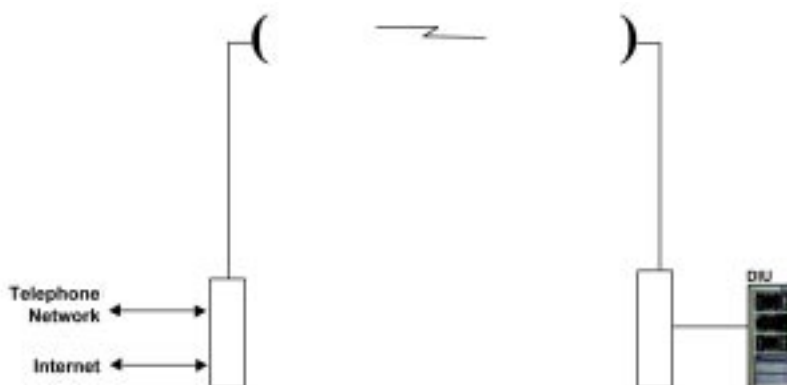


Figure 4.8(b) Microwave digital radio backhaul carrying voice and Internet traffic

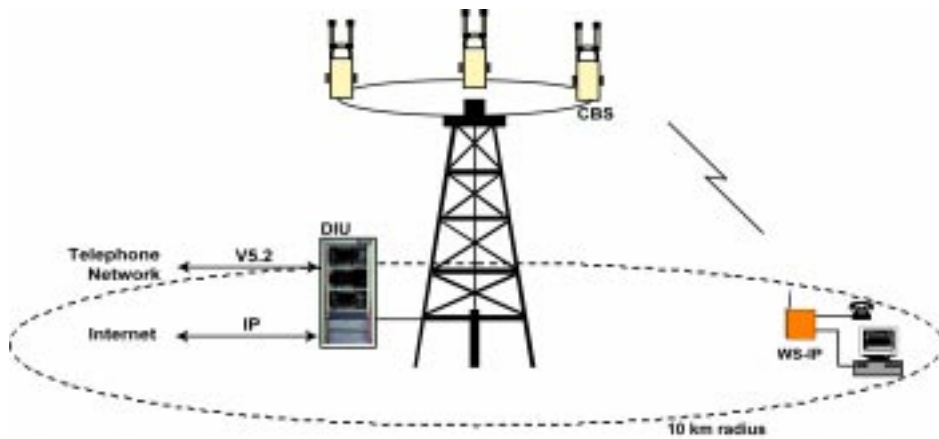


Figure 4.9 Deployment for a subscriber density greater than 1 subscriber per sq. km

A DIU along with a RAS could be located either in a rural exchange building or a RLU building, adjacent to a tower (typically 15 m to 35 m high). CBS's mounted on the tower can directly serve rural subscribers in a 10 km radius (or 300 sq. km area), as shown in Figure 4.9. This deployment scenario is adequate for a subscriber density higher than 1 subscriber per sq. km.

To serve a pocket of subscribers in a remote area, a BSD could be used. The BSD could then connect to up to four CBS's on a remote tower and serve subscribers in a 10 km radius around it, as shown in Figure 4.10. The BSD requires power back-up at the remote location. This deployment could be cost-effective for a subscriber density as low as 0.2 subscribers per sq. km, provided a digital microwave or fibre link to the BSD is available.

If such E1 links are not available, a cost-effective rural deployment would use Relay Base Stations. The RBS could be mounted on a tower up to 25 km away from the CBS tower, providing a LOS link between the RBS and the CBS. To overcome the problem of larger propagation delay from the RBS to the CBS, the RBS transmission is appropriately advanced as discussed in section 7.2.2 of Chapter 7.

Each RBS serves subscribers in a 10 km radius, as shown in Figure 4.11. The RBS has 11 channels and can be used to establish 11 simultaneous calls. The two-hop radio link provides the same voice and Internet services to the subscribers as a single-hop link. To the subscriber, the connection through the RBS is transparent. The RBS does require a power supply with appropriate back-up, which is provided

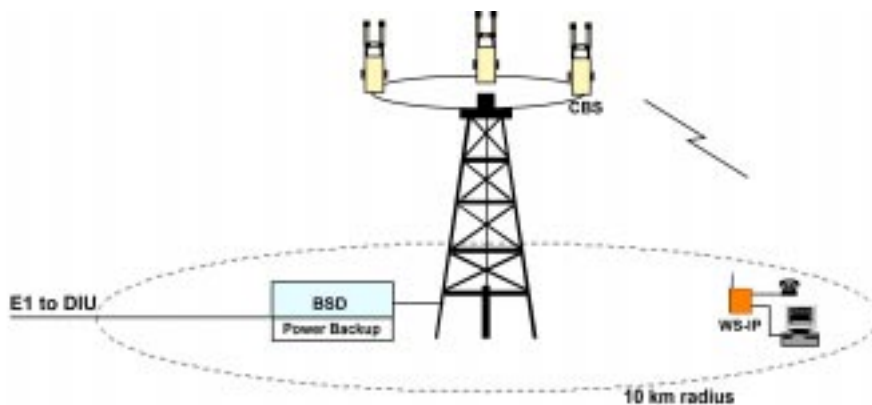


Figure 4.10 Rural deployment using BSD

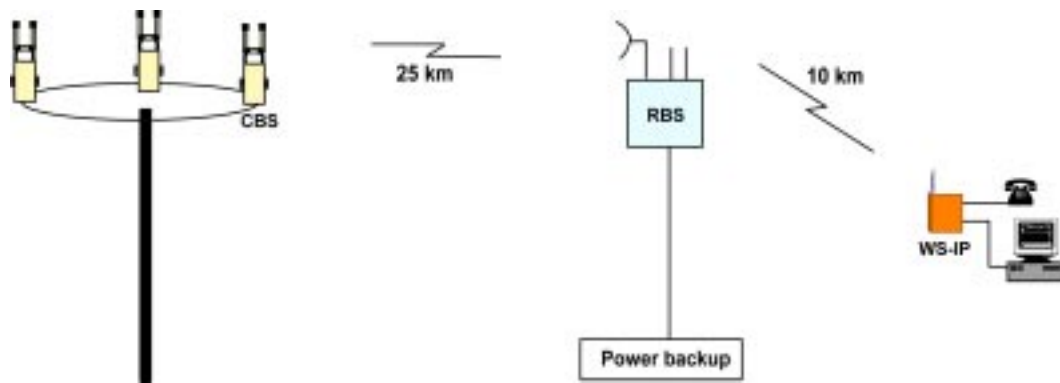


Figure 4.11 RBS serving remote subscribers in a 10 km radius

by a mains supply or a solar panel. The RBS can effectively cater to a subscriber density as low as 0.2 subscribers per sq. km.

Use of the RBS therefore enables a corDECT system to provide service in a 25 km radius. With the DIU (along with the RAS) deployed at the centre of a circle, the CBS's would be typically deployed in six sectors. While subscribers in a 10 km radius would be served directly by these CBS's, an RBS tower deployed in each of the surrounding cells, as shown in Figure 4.12, would enable 25 km coverage. One or more RBS's could be deployed in each cell, depending on the number of subscribers that need to be served in the cell.

Thus, we see that by properly engineering the deployment, it is possible to cost-effectively provide telephone as well as Internet service to

rural subscribers in an area with a very low subscriber density.

4.5 Franchise Access Provider

As the Access Network is the most difficult part of the telecom network to deploy, and the most expensive and difficult part to maintain, it may make sense for an operator to use Franchise Access Providers (FAP's) to install and maintain the last-mile access network. A FAP would provide service in a locality and would connect to the operator's backbone network.

The corDECT system could provide an ideal solution for such FAP's. The DIU acts as an in-dialing PBX, with billing and subscriber management available at the DIU itself. The DIU would be given a level in the numbering plan for switching incoming calls to it. The connection to

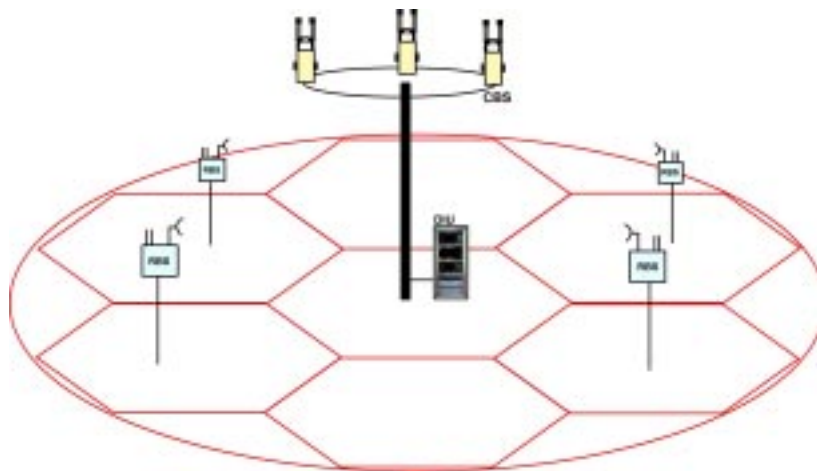


Figure 4.12 Sectorized RBS deployment

the Local Exchange (of the FAP) would be an E1 trunk with R2-MF signaling for incoming calls. All the incoming calls meant for the DIU would be switched by the LE on this trunk interface. The DIU would then complete the switching to the subscriber. For outgoing calls, either the trunk lines with R2-MF signaling, or subscriber lines (using CSMUX), could be used.

In all other ways, this deployment scenario appears similar to that of an Access Centre. The CBS's would typically be co-located with the DIU; yet some CBS's could be remotely mounted using either twisted-pair wires or a BSD. The Internet traffic is separated at the DIU and is sent

to the RAS. The statistically-multiplexed IP traffic at the RAS is then output to an Internet router through the Ethernet interface at the RAS and one of several possible ways of establishing a leased connection from the Ethernet port to the Internet router could be used.

A FAP could also connect Internet servers at the Ethernet interface (co-located with the RAS and DIU) and provide services such as mail server, web-server, etc. It is also possible to co-locate a RADIUS server, used for Internet billing and accounting, at this place. An integrated billing software for voice calls and Internet service is available (see Chapter 8).

5.1 Introduction

The corDECT WLL system provides features and services comparable to the best wireline systems. In the Switch (Local Exchange) Mode, it boasts of all the features of a large digital exchange. The Wallset IP provides simultaneous voice and Internet access (like an ISDN line) as a basic feature that all subscribers can have. Base Stations can be deployed in a multitude of ways, some suited to an incumbent operator, some to a greenfield operator, and others that enable coverage of sparsely populated rural areas. The system also has sophisticated Operations and Maintenance support and a Network Management System for managing a corDECT network. The next few sections describe some key features of the corDECT system.

5.2 Voice Quality

corDECT delivers the same toll-quality speech performance as a good copper-based local loop. Toll-quality voice is ensured by using 32 kbps ADPCM for voice digitization as per the ITU-T G.726 standard. ADPCM also ensures transparency to DTMF signals for Interactive Voice Response Systems.

5.3 Data Services

The employment of 32 kbps ADPCM permits all voice-band data services available from a conventional wired connection. It is also possible to occupy a double time slot on air to transmit at 64 kbps with error correction. This can be used for data connectivity at speeds similar to the best wireline speed. The speed of a modem/G3 fax supported using 32 kbps ADPCM is 9600 bps,

but with a double slot connection V.34 and V.90 modems can operate at full speed.

5.4 Internet Access Speed

Internet Access is possible simultaneously with a voice call using the Wallset IP. There are two access rates: 35 kbps and 70 kbps, using one and two time slots respectively.

5.5 Payphone/PCO

The system supports payphone with battery reversal as well as 12 kHz/16 kHz metering pulses. The pulses are provided by the Wallset for an external charge meter. The system also supports a CCB payphone (battery reversal only).

5.6 System Capacity

Each corDECT system supports up to 1000 subscribers. Its Base Stations can evacuate more than 150 E of traffic and funnel it to the telephone network and Internet using up to eight E1 links.

5.7 Air Interface Transmit Power

The power transmitted by a Wallset or Base Station nominally is 250 mW during the burst, or about 10 mW on the average. This ties in with the need for small cells to enhance frequency re-use and also conserves battery power.

5.8 Typical CBS Coverage

The coverage achieved by corDECT is 10 km in Line-of-Sight (LOS) conditions, made possible by enhanced receiver sensitivity, a patented timing adjustment feature and compact high gain antennas. The non-LOS (NLOS) coverage varies

from 400 m to 1 km depending on the way the CBS's are installed. Chapter 7 provides further details.

5.9 Typical RBS Coverage

The Relay Base Station (RBS) can be at a maximum distance of 25 km from the CBS and it can serve subscribers in a 10 km radius around it. The RBS is primarily meant to be used in rural or sparsely populated areas. It also finds occasional use in urban areas for covering regions in shadow.

5.10 Authentication and Subscription

Authentication is the process by which a corDECT subscriber terminal is positively verified as belonging to a legitimate subscriber of a particular DIU. It is invoked during call setup for every call. It can also be invoked during other circumstances like termination of access of a Wallset by the DIU. Authentication involves an Authentication Key which is never transmitted on air. The keys are maintained securely in the system and are inaccessible to anyone.

Subscription is the process by which a subscriber is added/deleted from the system and the features the subscriber desires to have are enabled. It is also the process by which the system formally transfers the identity, such as subscriber number, to the Wallset. The DECT standard specifies the usage of "On-Air Access Rights" procedures for the Wallset to obtain access rights to the system.

The Wallset can use this to:

- (i) gain access to the system and make calls and
- (ii) recognize the system in order to receive calls.

The DIU can use this to:

- (i) validate service requests from WS,

- (ii) limit access to classes of service, and
- (iii) recognize calls for valid Wallsets in order to route calls to them.

5.11 Major Subscriber Services

The corDECT system when operating in Switch Mode provides all the services of a large modern exchange. All the features and services specified by major telecom administrations (like the Indian Department of Telecommunications) in their Large Exchange Specifications are supported. Some of the important services are:

- Standing Alarm Call Service
- Occasional Alarm Call Service
- Call Completion Supplementary Services
 - Absent subscriber
 - Do not disturb subscriber
 - Call waiting
 - Dual telephone number
- Call Offering Supplementary Services
 - Call diversion on no reply
 - Call diversion on busy
 - Call diversion unconditional
- Call Restriction Supplementary Services
 - Outgoing only lines
 - Incoming only lines
 - Outgoing call restriction service
- Charging and Charge Debiting Supplementary Services
 - Subscriber call charge meter
 - Subscriber bulk meter
 - Non metered lines
 - Automatic transferred charge call (collect call)

- Three-Party Conference Calling
 - Billing for conference call
- Rapid Call-Setup Supplementary Services
 - Abbreviated dialing
 - Fixed destination call on time-out
- Non-Supplementary Services
 - Payphone service
 - Malicious call identification
 - Ring-back facility
 - Interception of calls
 - Priority lines
 - CLI and CLI restriction
- Measuring BHCA (regular measurement)
- Measuring Erlang for a period (occasional measurement)
- Measuring call attempts (regular and occasional)
- Logs for congestion
- Periodic testing of subscribers
- Periodic testing of junctions
- Facility for multiple printers
- Facility to execute commands from calendar
- Copy switching in hot standby mode

5.12 Major Switch Features

The corDECT system when operating as a Local Exchange, provides the operator extensive numbering, routing, traffic monitoring, and testing facilities. The major features are:

- Exchange Code Numbering Plan
- Digit Analysis – Access Check
- Digit Analysis – Routing
- Digit Analysis – Charging
- Operator Trunk Offer
- Temporary Out-of-Service Subscriber
- Hunting for a Group of Subscribers
- Subscriber Line Supervision
 - Speech monitoring by intelligence agency
 - PSTN line supervision
 - Total exchange meter and junction metering
 - Measuring subscriber supplementary service utilization

5.13 OMC Features

The corDECT system's Operation and Maintenance Console supports the following:

- System Administration Features
 - Subscriber administration
 - E1 line administration
 - Traffic measurements
 - Billing database
 - PSTN ports and CBS administration
- System Maintenance Features
 - Health monitoring of all DIU cards and sub-systems
 - Facility to test E1 interface
 - Monitoring of CBS/BSD interface
 - CBS software upgradation
 - Alarm conditions
 - Log files
 - Silent polling of Wallsets from the DIU
- Traffic Analysis
 - Exchange traffic
 - CBS traffic
 - Subscriber traffic
 - Total number of call attempts

- Total number of successful calls
- Call failures
- Holding time of calls
- Traffic on CPU of OMC
- Traffic on printer

5.14 Maximum CBS-DIU Copper Distance

Two versions of the CBS are available: one supporting a maximum loop resistance of 540 Ω (3 km copper) and the other a maximum loop resistance of 820 Ω (4 km copper). In both cases, a mix of 0.4 mm and 0.5 mm diameter copper wire can be used.

5.15 Maximum CBS-BSD Copper Distance

The BSD supports a maximum loop resistance of 200 Ω , with a mix of 0.4 mm and 0.5 mm diameter copper wire.

5.16 DIU Power Supply

The DIU works off a -48 V DC exchange power supply. The current requirements are very modest. A fully loaded DIU typically requires, at most, 14 A and significantly less if the CBS's are at short distances from the DIU. If the CSMUX is employed in the Transparent Mode of operation, an additional 3 A is needed for every 240 lines.

5.17 Wallset and Multiwallset Power Supply

Wallset IP: The Wallset (or WS-IP) is powered from the mains through an external 12 V adapter

drawing a maximum of 500 mA. The backup battery is a 6 V/1.3 Ah sealed lead-acid rechargeable type.

Multiwallset: The Multiwallset is powered from the mains (85 V - 265 V AC, 45 - 65 Hz) and has a 12 V/7.2 Ah sealed lead-acid rechargeable battery for back-up. The Multiwallset draws a maximum of 50 VA from the mains.

5.18 Wallset and Multiwallset Talk Time/Standby Time

The Wallset IP has a talk time of 3.5 hrs and a standby time of 16 hrs.

The Multiwallset has a talk time of 4 hrs/line and a standby time of 16 hrs.

5.19 RBS Power Supply

The RBS is a stand-alone unit. The required supply is drawn from any one of three sources:

- 95 to 265 V AC mains
- 40 W solar panel (of approximate size 88 x 44 cm)
- 12 V/40 Ah rechargeable maintenance-free lead-acid battery

This design ensures 36 hrs operation on any one of the three power sources and the battery can be charged by any of the other sources.

Alternatively, if a -48 V DC battery-backed supply is available, it can be used to power the RBS.

5.20 BSD Power Supply

The BSD is powered by -48 V DC and requires a maximum current of 1.3 A.

5.21 Other Features

5.21.1 Physical Dimensions

| | | |
|---------------------|-------------------------------------|----------------------------------------|
| DIU | 145 cm (H) x 55 cm (W) x 33 cm (D) | |
| CBS | 24 cm (H) x 16.5 cm (W) x 9.5cm (D) | |
| Wallset | 20 cm (H) x 20 cm (W) x 4 cm (D) | |
| BSD | 8 cm (H) x 45 cm (W) x 18.5 cm (D) | |
| Multiwallset | DTM | 10.5 cm (H) x 10.5 cm (W) x 7.5 cm (D) |
| | SIM | 27cm (H) x 20 cm (W) x 12 cm (D) |
| RBS | Air Unit | 23 cm (H) x 30 cm (W) x 8.5 cm (D) |
| | Ground Unit | 23 cm (H) x 30 cm (W) x 8.5 cm (D) |

5.21.2 Weights

| | | |
|---------------------|-------------------------------|--------------------------|
| DIU | 90 kg approx. | |
| CBS | 1 kg approx. without fixtures | |
| Wallset | 1.3 kg | |
| BSD | 2 kg | |
| Multiwallset | DTM | 0.4 kg |
| | SIM | 3.2 kg |
| RBS | Air Unit | 1.5 kg |
| | Ground Unit | 1.5 kg (without battery) |

5.21.3 Environmental Conditions

All the sub-systems meet the Indian Department of Telecommunication's environmental specification QM333. They are also compliant to the relevant ETSI/IEC/CISPR EMI/EMC specifications.

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6.1 Introduction

The corDECT system's modular design, along with its add-on sub-systems like the Base Station Distributer (BSD) and Relay Base Station (RBS), permits the operator to dimension the system to cater to a wide range of subscriber densities, teletraffic levels, and deployment scenarios. In this chapter, we discuss the traffic-carrying capacity of the system for voice and Internet services. The discussions below consider the case of 35 kbps Internet access.

6.2 System Capacity

Each DIU can support up to 1000 subscribers, irrespective of whether they are connected using Wallset, Wallset IP, or Multiwallset. All subscribers can have both voice and Internet access, thus providing the equivalent of 2000 lines in a conventional wireline system.

The maximum number of Compact Base Stations supported by a DIU is 20. A BSD provides remote support to four CBS's, in lieu of four connected directly to the DIU. Each DIU currently supports up to eight E1 links, which can be used to carry voice traffic to PSTN and Internet traffic to the

RAS's. There is no limit to the number of RBS's that can be deployed; however, a RBS cannot be daisy-chained to another RBS.

6.3 Traffic Capacity of CBS

A CBS can support 12 simultaneous voice/Internet calls. At 1% Grade of Service (GOS), 12 channels can support 5.8 E traffic. If all 20 CBS's in a system are deployed in distinct coverage areas, a total of 116 E traffic can be supported. These distinct coverage areas can be circular cells, or angular sectors, as illustrated in Figure 6.1. The former uses omnidirectional antennas, while the latter requires directional antennas.

When two CBS's are deployed covering the same area (cell or sector), a subscriber can access one of 24 channels, since a call can be placed through any CBS. With 24 channels, 15.3 E traffic can be supported at 1% GOS. Thus there is a significant gain in capacity (7.6 E per CBS now) when two CBS's share a common coverage area.

If the number of CBS's servicing a cell or sector is increased to three, 36 channels carry 25.5 E at 1% GOS. This is equivalent to about 8.4 E per CBS, amounting to an even more efficient use of the 12 channels available per CBS.

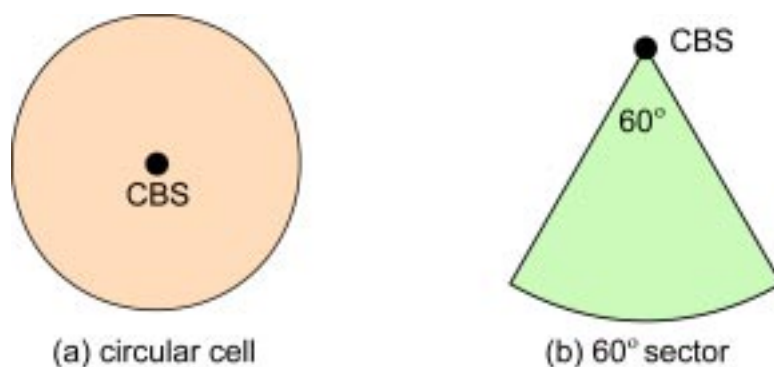


Figure 6.1 Circular and sectoral deployment

Thus, when a cell is divided into six sectors and each sector is serviced by three CBS's each, a total of 153 E can be evacuated from just one site, assuming that there are sufficient DECT channels available to do so. We shall see in a later section that this is indeed possible.

If a CBS with omnidirectional antennas is deployed in addition to those serving the six sectors, as depicted in Figure 6.2, the capacity goes up significantly. This is because the omni CBS handles the overflow traffic from all the sectors. Only if a call cannot be serviced either by the CBS's in a sector or by the omni CBS, is it blocked. Since the omni antenna will have lower gain than the sectoral antenna, a call will be usually serviced by the sectoral CBS's. With three CBS's per sector in six sectors and two omni CBS's (20 CBS's in all), the total traffic that can be evacuated is approximately 176 E, amounting to 9 E per CBS.

6.4 Traffic Capacity of the DIU

The traffic evacuated by the CBS is delivered to the DIU, which is a non-blocking switch. That is, all 240 channels from 20 CBS's (12 x 20) and all 240 channels from eight E1 links (30 x 8), can be switched without blocking. Hence, the DIU can be ignored while determining traffic capacity.

The DIU supports up to eight E1 ports towards the RAS and PSTN. The maximum number of

calls that can be set up through 20 CBS's is 240, which is the same number of circuits supported by eight E1 ports. The E1 ports can be apportioned between voice and data as desired, depending on an estimate of the relative proportion of voice and Internet calls. For example, of the 150 E that can be evacuated by 18 CBS's (in a six-sector cluster), let the voice and Internet traffic be 75 E each. If we generously assign four E1 ports for voice traffic and four ports to the RAS's, each set of four E1 ports support 75 E traffic with negligible blocking.

Hence, the overall GOS, taking into account blocking on air as well as blocking at the E1 ports, is close to 1%. However, only three E1 ports each need be assigned to voice and Internet traffic, as the traffic supported by three E1's is 72 E with 0.5% GOS. The CBS's support a total of 144 E at 0.5% GOS, giving an overall GOS of 1%.

If the voice traffic component is 100 E instead (say, 0.1 E per subscriber), we need to assign four E1 ports for voice. These can carry 100 E traffic with 0.5% GOS. The Internet calls are assigned two E1 ports, which support 45 E traffic with 0.5% GOS. The CBS's can evacuate a total of 144 E with 0.5% GOS, resulting once again in an overall GOS of 1%.

Thus, the E1 ports can be assigned to voice and Internet traffic in the proportion needed, depending

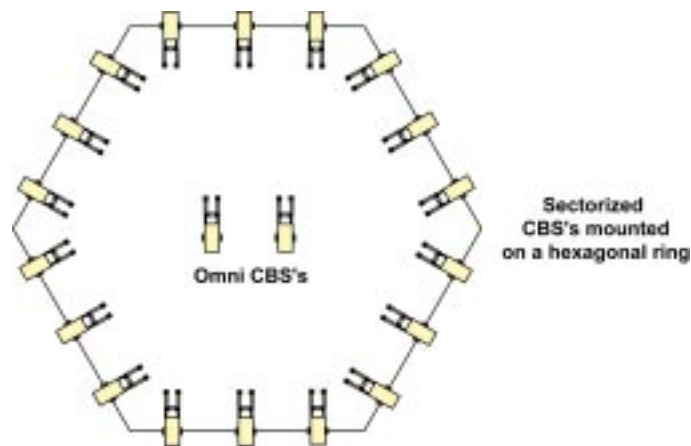


Figure 6.2 Three CBS's per sector and two omni CBS's

on the requirements. The upper limit to the traffic carried in the corDECT system comes from the maximum limit of 20 CBS's, which provide 240 active voice/Internet channels at any given time.

6.5 Traffic Dimensioning from RAS to Internet

The RAS statistically multiplexes the bursty IP packet traffic from several subscribers. The bitrate of the link from the LAN port of the RAS's to the Internet can be significantly less than the total bitrate of the E1 ports connected to the RAS's.

The concept of activity factor plays a role here. The activity factor is the fraction of the peak bitrate a subscriber uses on the average. For example, a user may have only 3 kbps average throughput on a 35 kbps link due to the bursty nature of traffic, representing an activity factor of around 10%. Since each RAS has two E1 ports (60 channels) towards the DIU, with 3 kbps throughput per channel, the total throughput of the RAS is only 180 kbps.

During a burst of packets, however, the bitrate can reach the peak value. Of the 60 calls simultaneously supported by a RAS, a certain small fraction may pump data at the peak rate at the same time. For the subscribers to get quick response, the link between the RAS and the Internet router needs not only to have a capacity equal to the total throughput (activity factor x 30 x number of E1 ports carrying Internet calls), but also close to the total simultaneous peak traffic. For example, if 10 out of 60 calls are expected to simultaneously have peak traffic of 35 kbps, the peak rate would be 350 kbps and the link from the RAS to the Internet needs to have a bitrate of 350 kbps.

6.6 Re-Use Efficiency in corDECT

The corDECT system employs the DECT standard, one of whose stellar features is

Dynamic Channel Selection (DCS). A brief introduction to the DECT standard is given in the Appendix. The main aspects of DCS relevant to our discussion at this point are (i) no frequency planning is required, (ii) at any point in space and time the Wallset (WS) chooses the strongest CBS to lock to and the quietest channel to set up a call (the WS selects the channel for both outgoing and incoming calls), (iii) with 10 frequencies, 120 channels (in a 17.28 MHz band) are available for each WS to choose from, and (iv) a WS hands over the call seamlessly to another channel even while a call is going on, if a significantly better channel is found. The WS continuously scans all channels and updates its table of channel quality.

The DECT standard has excellent specifications for receiver performance in the presence of co-channel and adjacent channel interference. The corDECT system has significantly better performance than specified by DECT in many of these categories. The net result is that a subscriber can establish a call even with a Carrier-to-Interference (C/I) ratio as low as 10 dB.

In corDECT WLL deployment, extensive use is made of directional antennas. These give several advantages apart from high gain. Being directional, the transmitted power is primarily focussed in one direction and the antenna has a high front-to-back ratio. These contribute towards reducing interference.

All these factors contribute to making corDECT a very high capacity system with excellent frequency re-use.

6.7 Capacity of Multi-Cellular Tower-Mounted CBS Cluster

We have seen that three CBS's serving one 60° sector support 25.5 E traffic at 1% GOS, provided DECT channels are available to set up the calls. The question, therefore, is: what traffic level can

actually be supported per cell in a multi-cellular deployment, when each cell has six sectors with multiple CBS's in each sector?

This question has been investigated extensively, taking all types of interference (co-channel, adjacent channel and intermodulation) and non-idealities (e.g., non-ideal antenna radiation pattern) into account.

Figure 6.3 depicts the sectorized multi-cellular deployment. It also indicates, for one sector, the few regions in which the interference is significant. The use of directional antennas at CBS and WS restricts the interference-generating regions to a minimum. It must also be remembered that all the CBS's transmit together in one 5 ms period, as do the Wallsets in the next 5 ms period. Thus, when a Wallset is receiving from a CBS, interference is present only from other CBS's in the vicinity. Likewise, interference to a CBS can come only from WS transmissions.

Simulations indicate that about 200 E can be evacuated per cell (i.e., 33 E per sector) at 1% GOS in a six-sector multi-cellular deployment. This will, of course, require more than three CBS's per sector. Thus, the traffic of 25 E that three CBS's can handle per sector is easily supported on air. Even with a couple of additional omni CBS's, DECT channels can be found for evacuating the maximum capacity of 176 E per cell.

The total capacity of a cell for a different number of CBS's is shown in Table 6.1.

We see that a configuration can be found for any traffic level from 6 E to 180 E. It is possible to deploy additional CBS's as the subscriber base and consequently the traffic, grows. The omni CBS, apart from increasing capacity, also provides redundancy in case of CBS failure. A DIU located in one cell which is only partially loaded with CBS's can, for example, support eight CBS's (six-sector deployment with one CBS per sector and two omni CBS's) and evacuate

| CBS configuration | Capacity at 1% GOS |
|------------------------|--------------------|
| 1 omni | 5.8 |
| 2 omni | 15.3 |
| 3 omni | 25.5 |
| 1 x 6 sectors | 34.8 |
| 1 x 6 sectors + 1 omni | 50.0 |
| 1 x 6 sectors + 2 omni | 65.0 |
| 2 x 6 sectors | 91.8 |
| 2 x 6 sectors + 1 omni | 102.0 |
| 2 x 6 sectors + 2 omni | 131.0 |
| 3 x 6 sectors | 153.0 |
| 3 x 6 sectors + 1 omni | 158.0 |
| 3 x 6 sectors + 2 omni | 176.0 |

Table 6.1 Capacity of six-sector cell for different CBS configurations

65 E traffic from an adjacent cell. Two BSD's can be used to link the eight CBS's at the adjacent site to the DIU. Thus the corDECT system is highly modular, enabling great flexibility in deployment.

6.8 How High Capacity is Achieved

Simple calculations help establish how the capacity of 153 E per site (in a six-sector, three CBS/sector configuration) is possible. To service 25 E per sector, we need 25 channels on the average in each sector. It is highly improbable that the number of channels used will be more than this average number simultaneously in all sectors. That is, the total number of channels needed for six sectors will be close to 150 most of the time and not 216 (18 CBS x 12 channels per CBS), which is theoretically possible. With a front-to-back ratio of more than 20 dB for the CBS antennas, the same channel can be re-used



Figure 6.3 Multi-cellular deployment showing interfering regions

in sectors 180° apart. With this re-use within a cell, a cell needs only 75 channels to handle the total of 150 E traffic. Adjacent cells can also employ the same channels, DCS ensuring that a channel is re-used in a region where interference is low (such regions are shown unshaded in Figure 6.3). In any case, 45 more channels are available to choose from in case a channel cannot be re-used in adjacent cells at certain times.

An alternative way of understanding how such a high capacity is obtained, is to compute an equivalent re-use factor. In a system that requires frequency planning, the re-use factor is the number of sets into which the total number of channels are grouped for allocation to different sectors, so that the interference is within permissible limits. The smaller the factor, the more efficient the re-use, the larger the number of channels available per sector. In TDMA systems like GSM, a re-use factor of four is now common. In a six-sector corDECT cell supporting 176 E traffic (see last entry in Table 6.1), we need 30 channels per sector. This implies an equivalent re-use factor of four, given that we have 120 channels in all. Since, the equivalent re-use factor with DCS is typically much higher than in a frequency-planned system, a factor of four is not surprising at all.

6.9 Capacity in High-Rise Metropolitan Deployment

When the buildings in an area are very high (eight storeys or more), the modular CBS along with the BSD can be exploited to support very high subscriber density.

The CBS can be deployed on the corners of the roof of a high-rise building, with directional antennas. The CBS in each corner illuminates one or more faces of several buildings in the vicinity. Each building will have at least several 10's of potential subscribers. One or more CBS's can serve the corDECT subscribers in these illuminated buildings. Since sufficient signal strength will be available inside the building on all floors on the illuminated sides, WS deployment is easy. The number of CBS's required per corner will depend on the traffic.

DECT channel availability is hardly an issue in this type of deployment. The channels can be re-used on every street, since the large buildings themselves block interference from neighboring streets. DCS will ensure that the channels are optimally chosen for each call.

This type of deployment will have CBS sites every 400 m or so on a street and typically on alternate streets. The CBS can be connected to the DIU

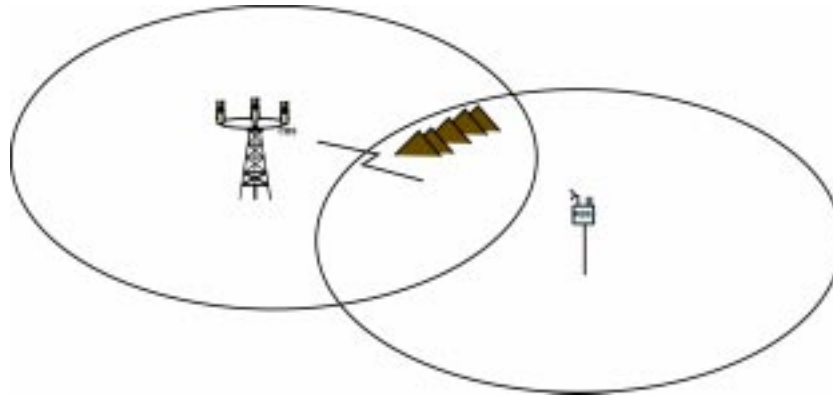


Figure 6.4 RBS providing coverage to shadow area

using three pairs of copper (per CBS), if copper is available. Alternatively, if fibre connectivity is available, the BSD can be used to connect the CBS to the DIU by using an E1 link provided by the optical fibre system. The BSD can also be deployed with HDSL modems, which support an E1 link on a single copper pair.

6.10 Capacity of RBS

A RBS can support up to 11 simultaneous calls. At 1% GOS, this gives a capacity of 5.1 E. Thus, for example, one RBS can easily support nearly 75 rural subscribers at 0.07 E per subscriber. The CBS dimensioning is done by adding the traffic handled by the RBS in a sector, to the traffic emanating from WS's directly served by the CBS. The GOS for subscribers served by an RBS is determined by adding the GOS of the CBS's to the GOS of the RBS. For example, if the RBS as well as the CBS in a sector provide 1% GOS, the overall GOS for an RBS subscriber is 2%. This can, however, be made close to 1% by increasing the number of CBS's (typically one more CBS will do) so that the blocking probability of the CBS becomes negligible.

If the area served by an RBS site happens to have high subscriber density, or heavy traffic, multiple RBS's can be deployed on the same tower. Two RBS's, with 22 channels, gives a traffic capacity of 13.7 E at 1% GOS. Once again, the flexibility of corDECT comes to the fore in enabling an operator to meet any situation in the field.

A typical rural deployment using RBS is shown in Figure 4.12 of Chapter 4. If we assume that each of the cells surrounding the central cell has about 75 subscribers generating a total of 5.1 E traffic per cell, one RBS will be sufficient in each cell. The central cell may have about 200 subscribers (since it also possibly contains the main town of the area) generating, say, 20 E traffic among them. The total traffic is 50.6 E ($6 \times 5.1 E + 20 E$), indicating that one CBS per sector along with one omni CBS (having a capacity of 50 E, as per Table 6.1) will suffice. High traffic levels in any of the surrounding cells can be handled by adding a second RBS in that cell, as well as an extra CBS in the corresponding sector of the central cell serving that RBS.

Finally, an RBS site may occasionally be deployed such that its coverage area overlaps partially with that of a CBS, in order to serve a shadow area created by a topographical feature. This is illustrated in Figure 6.4.

6.11 Summary

We have seen that, with just 120 channels in a 17.28 MHz band, corDECT can support both a large coverage area (25 km radius) and traffic density as high as 2000 E/sq. km (20 E in a 200 m x 50 m high-rise area). The corDECT system can be easily dimensioned and deployed in a modular and cost-effective manner.

Chapter 7 Air Interface Link Budgets and Cell Planning

7.1 Introduction

The DECT standard, on which corDECT is based, originally focussed on high subscriber density, high traffic capacity, low cost, microcellular deployment, in applications such as wireless local loop, wireless PBX, pedestrian PCS, and home cordless systems. The standard supports toll-quality voice service and high bitrate data services, with a number of features that are available only in 2.5G and 3G mobile cellular standards. All these capabilities make DECT immensely attractive for the WLL application, provided one finds ways to deploy a DECT-based WLL system with a wide range of cell sizes. The desired cell radius could be anywhere from 0.5 to 3 km in urban areas and up to 20 to 25 km in rural areas.

7.2 corDECT Enhancements

7.2.1 Improved Sensitivity

The DECT standard requires the sensitivity (defined as received power level at which the Bit Error Rate is 10^{-3}) to be only -83 dBm for the Wallset and -86 dBm for the Base Station. In corDECT, the sensitivity achieved is typically

-91 dBm. While the sensitivity indicates the minimum received signal level that is acceptable, one would want to have a Bit Error Rate (BER) lower than 10^{-5} most of the time. The DECT standard requires that at -73 dBm, the BER should be better than 10^{-5} . In corDECT, this has been improved to -86 dBm. Thus, the link quality in corDECT will be very robust as long as the received level is more than -86 dBm. An occasional reduction in received power due to fading is acceptable, as long as the level rarely drops below -91 dBm.

7.2.2 Timing Adjustment

As in any TDMA standard, a guard time is introduced in DECT between time slots. This allows for the transmission in one slot from a distant WS (which travels longer) to arrive a little late, without interfering with the signal in the next slot which may arrive at the slot edge. This is illustrated in Figure 7.1.

The guard time provided in the DECT standard allows for the WS to be only a maximum of 5 km from the CBS. This was considered adequate for the intended applications and for the sensitivity specified.

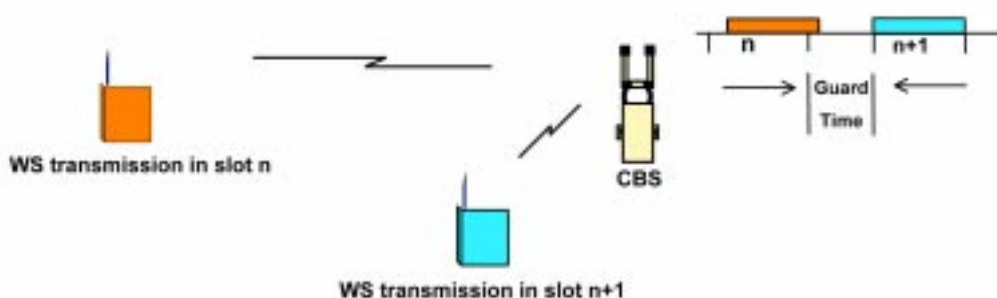


Figure 7.1 Time-of-arrival of signals from two WS's at differing distance from CBS

With the improved sensitivity in corDECT and the availability of low-cost, high-gain antennas (see section 7.2.3), it is easy to get the required signal level at a distance much greater than 5 km, under Line-of-Sight (LOS) conditions. In order to take advantage of this, a patented timing adjustment scheme is incorporated in corDECT. In this scheme, the subscriber terminal (WS/WS-IP/MWS) and RBS adjust their transmission based on the distance from the CBS, thus ensuring that the signals are received by the CBS within their respective time slots. Using this technique, the WS can be as far as 10 km and the RBS as far as 25 km, from the CBS. The difference in maximum range in these two cases comes from the respective link budget constraints, as we will see in the following sections.

7.2.3 Low-Cost, Compact, High-Gain Antennas

The frequency of operation in DECT is around 1.9 GHz, at which the wavelength is only 15 cm (approximately). Compact, but high-gain, patch antennas that are also inexpensive, can be designed for such high frequencies. Several antennas have been specifically developed for the corDECT system. A few are shown in Figure 7.2.

A 7.5 dB patch antenna (Figure 7.2 (a)) is most commonly used for the WS/WS-IP. This antenna weighs a mere 150 gm, has a horizontal beam

width (HBW) of approximately 80° and a vertical beam width (VBW) of approximately 50° . This means that the antenna can be installed without any special aids, simply by visual alignment of the antenna towards the CBS. Its minimum Front-to-Back Ratio (FBR) is 15 dB, ensuring good rejection of signals from other CBS's in the vicinity. The MWS has a similar antenna built into its outdoor unit (called DTM).

A 12 dB antenna, with a HBW of 60° and VBW of 25° , is shown in Figure 7.2(b). This antenna is primarily used for sectorized deployment of the CBS. Like the 7.5 dB WS antenna, it is light (~300 gm) and small. Its minimum FBR is 20 dB, ensuring good frequency re-use when deployed with CBS's in sectors 180° apart.

If a CBS is to be deployed with 360° coverage, the omnidirectional antenna shown in Figure 7.2(c) can be used. It has 6 dB gain and 10° VBW. Similar antennas with 9 dB and 11 dB gain are available. Their VBW is smaller, necessitating accurate verticality during mounting.

A small and light grid antenna with a gain of 20 dB is available for use with the RBS, for the RBS-CBS link. This high-gain antenna ensures a sufficient signal level even at a distance of 25 km.

These low-cost, specialized antennas and associated low-cost cables, are key components

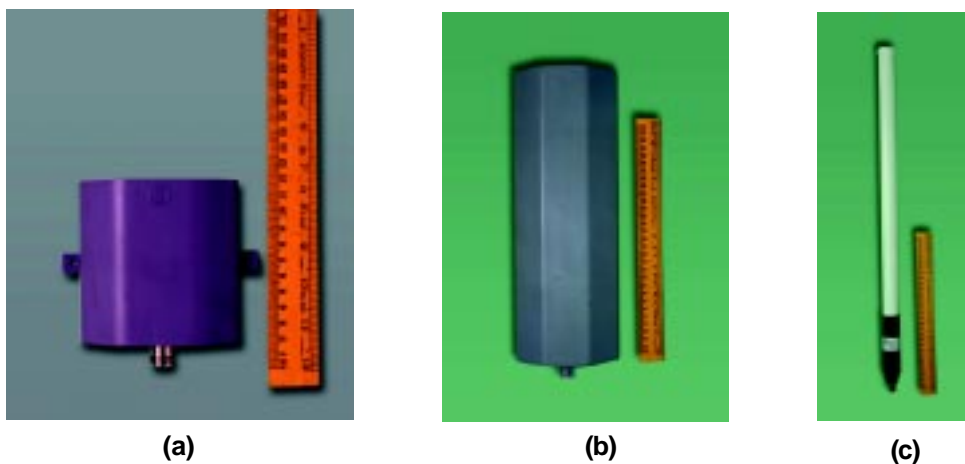


Figure 7.2 Three different antennas

of the corDECT system that make it a versatile WLL system. The antennas, cables, and accessories are robust and weatherproof, designed to function for several years without deterioration.

7.3 Link Budgets with corDECT

The transmit power and sensitivity for all corDECT sub-systems are nearly the same and as mentioned above, significantly better than the minimum specified in the DECT standard. For the purpose of link analysis, we take the transmit power as 23 dBm and the sensitivity as -90 dBm. Thus, the link budget is $113+G_B+G_w$, where G_B and G_w are the antenna gains at CBS and WS, respectively.

In the case of the RBS, G_B and G_w represent the RBS omnidirectional and WS antenna gains, respectively for the RBS-WS link, while they are the CBS and RBS grid-antenna gains respectively for the CBS-RBS link (see Figure 3.4 and Figure 3.11, Chapter 3).

7.4 Path Loss Models

The loss 1 m from an antenna at 1.9 GHz is 38 dB ($=20\log_{10}\lambda/4\pi$). To this, we add a loss of $20\log_{10}d$ (where d is in metres), when the link is Line-of-Sight (LOS). When the link is non-LOS (NLOS), the path loss model is more complicated. For the case when the CBS is mounted on the rooftop (say, on a 3 m pole on the roof) a loss model recommended by ETSI [ETR 139, Nov. 1994] is $38+20+35\log_{10}(d-10)$ for $d>10$ m. Here, it is assumed that the loss is as in free space (proportional to d^2) up to 10 m and proportional to $d^{3.5}$ thereafter. The model is presented in an equivalent simplified form in Table 7.1.

When the CBS is mounted on a mast/tower, rising high above the buildings, the loss model is even more complex. We denote by the term skyline the typical height of the buildings in the coverage

area. For example, in an area where many buildings are three-storeyed (G+2), the skyline would be 10 m. When the tower is significantly higher than the skyline (e.g. if the tower height is double the skyline), the free-space component is significantly larger than in the NLOS model for rooftop CBS deployment. The loss is a function of the proportion of the path that is free-space which, in turn, is a function of (i) tower height, (ii) skyline and (iii) distance between CBS and WS. A computer model, based on ray tracing, is used for this case. Table 7.1 summarizes the models discussed above.

In addition to the above loss models, it is useful to note that the loss at 1.9 GHz through a 9" brick wall or 5" RCC floor is about 7 dB. Thus, the signal strength outside a window is often 7 dB higher than that inside. Further, the loss through foliage at 1.9 GHz can be anywhere from 6 - 16 dB depending on the foliage density. Signals passing through the foliage of a tall but relatively thin tree (like a coconut or eucalyptus tree) undergo only about 6 - 7 dB loss, while a big, but shorter tree of, say, 10 m height gives a loss of 10 - 15 dB. However, it will generally be possible to get LOS by rising above the treeline in the latter case.

| Type of link | Loss Model |
|---------------------|------------------------------|
| LOS | $38+20\log_{10}d$, $d>1$ m |
| NLOS, roof-top | $23+35\log_{10}d$, $d>10$ m |
| NLOS, tower-mounted | Computer-based ray tracing |

Table 7.1 Path loss models

7.5 Fade Margins in corDECT

The corDECT system employs antenna diversity at the Base Station (at both the CBS and RBS), incorporating an important option provided by the DECT standard. Since DECT is a Time Division Duplex (TDD) standard and the same frequency

is employed in both directions of a link, it is sufficient to employ diversity at the Base Station alone. Antenna diversity reduces the fade margin needed by half. According to ETSI [ETR 139], the fade margin needed with diversity for the NLOS link is between 8 - 10 dB and that for the LOS link is between 4 - 5 dB. The lower limits are sufficient when the antennas employed have high gain. In corDECT deployment, we provide a fade margin of 10 dB for non-LOS links and 5 dB for LOS links. This fade margin ensures that the BER is less than 10^{-6} most of the time, going up to 10^{-3} only occasionally during fades.

7.6 Cable Losses

The corDECT CBS is designed for outdoor (rooftop/tower) mounting, very close to the antenna. The RF cables connecting the CBS to its antennas (two, for diversity) are nominally 0.5 m long. The loss is therefore less than 1 dB. The same is true for the RBS antennas.

In the case of the WS the cable length will vary, depending on the subscriber location. The WS, in general, will be inside the subscriber premises, close to a window. In case the subscriber is able to get NLOS coverage, the antenna will be mounted outside the window and the RF cable will be 1 - 3 m long. If the link is LOS, the WS antenna will be on the rooftop and the RF cable will be 3 - 10 m long.

Two types of RF cable are recommended for WS installation: a flexible (0.25 inches dia.) low-cost (LC) cable with a loss of around 0.5 dB/m and a low-loss (LL) cable with a loss of around 0.2 dB/m. The LC cable is sufficient for most WS installations and also for the CBS and RBS.

7.7 Link Analysis for corDECT

Let us now analyze corDECT links of different types and for different scenarios. In our computations below, we denote the total cable losses as LC (dB). Further, we refer to the excess

signal strength available over the sensitivity limit of -90 dBm as the link margin. The cable losses L_C also have to come from this link margin.

7.7.1 LOS Link

The link budget in this case (see section 7.3) is $113+G_B+G_W$, the path loss (see Table 7.1) is $38+20\log_{10}d$ and the fade margin is 5 dB. Thus, the maximum distance d is obtained from the constraint: $70+G_B+G_W-(L_C+20\log_{10}d) > 0$.

Let us consider the case of a 10 km LOS link between the CBS and WS. For a 12 dB sectoral antenna at CBS and a 7.5 dB patch antenna at WS, $(L_C+20\log_{10}d)$ can be at most 89.5. At 10 km distance, this implies that the link margin is 9.5 dB, which is ample for even the LC cable.

In case the lower-gain omni antenna (6 dB gain) is used for the CBS, the link margin is reduced to 3.5 dB at 10 km. We may now need to use either the LL cable or 12 dB antenna for a WS which is installed 7 - 10 km from the CBS.

Figure 7.3 shows the link margin available on a LOS link as a function of d , for $G_W = 7.5$ dB and for various values of G_B . The curves tell us how much margin we have (including cable loss) at various distances for various CBS antenna gains.

The RBS-WS link is similar to the one discussed above. We typically employ omni antennas with 6 or 11 dB gain for the RBS. The above analysis holds and Figure 7.3 can be used to determine the link margin at various distances from the RBS.

In the case of the MWS, $L_C = 1$ dB at the most (cable loss only on the CBS side). Therefore, a MWS can be deployed up to 10 km away irrespective of the CBS antenna type.

7.7.2 NLOS Link from Rooftop CBS

In the case of a NLOS link from a rooftop CBS, mounted just 3 - 6 m above the roof of a much taller building (12 - 20 m), the NLOS loss model $23+35\log_{10}d$ applies for $d > 10$ m (see Table 7.1).

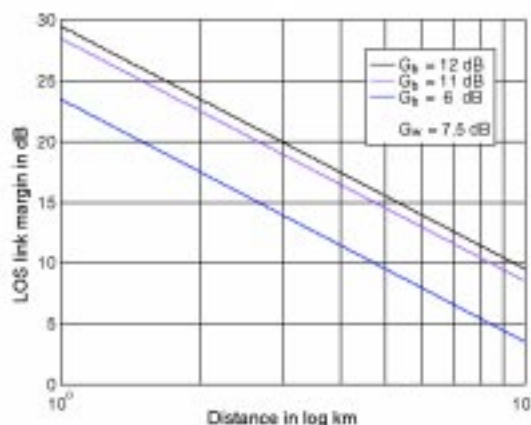


Figure 7.3 Link margin for LOS link vs. distance

Let us consider a 6 dB omni antenna at CBS and 7.5 dB patch antenna at WS. The link budget from section 7.3 is therefore 126.5 dB. The fade margin needed for a NLOS link is 10 dB and the total cable loss for an indoor NLOS installation is less than 2 dB, giving a total loss of 12 dB.

We are now ready to determine the maximum NLOS link distance for this case. It is given by the constraint $23 + 35 \log_{10} d > 126.5 - 12$, or $35 \log_{10} d > 91.5$. This gives d_{max} as 400 m. At distances less than about 250 m, even a whip antenna directly screwed on to the WS/WS-IP (thus avoiding an RF cable) will be sufficient.

In the case of a rooftop CBS deployment, the coverage area increases significantly if the building, on whose roof the CBS is installed, itself does not create a shadow for the other buildings in the coverage area. If the roof area is large, this

can be ensured by mounting multiple CBS, preferably with sectoral antennas, on the corners of the roof.

7.7.3 NLOS Link from Tower-Mounted CBS

Let us now consider the case of the CBS on a tower. Typically, the skyline for this type of deployment will be 7 - 14 m, (two to four storeyed buildings) and the tower will be 10 - 15 m above the skyline. This is illustrated in Figure 7.4.

The path taken by the RF signal between the CBS and WS has a significant free-space component in this case. The path loss is obtained using a computer model developed by the TeNeT Group, IIT Madras. Figure 7.5 shows the contour for which the mean signal strength received outside the window is -77 dBm, when

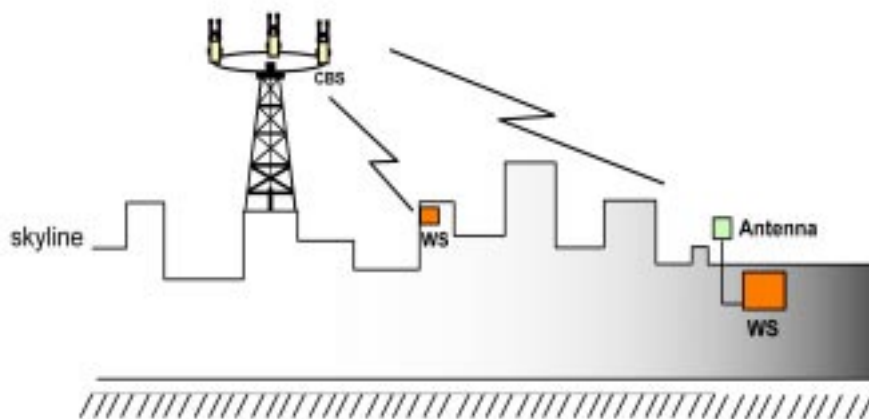


Figure 7.4 CBS's mounted on a tower above the skyline

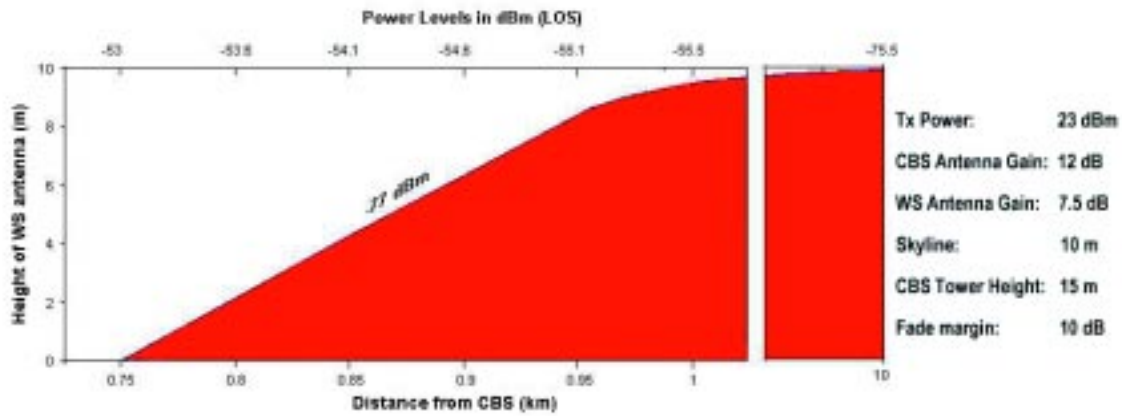


Figure 7.5 NLOS coverage as a function of distance for tower-mounted CBS

the skyline is 10 m and the tower height above the skyline is 15 m. The CBS antenna gain is taken as 12 dB and the WS antenna gain as 7.5 dB. The contour shown allows for a fade margin of 10 dB and 3 dB for cable loss L_c .

The region above the contour is the NLOS coverage region. The distance from the CBS is indicated on the bottom x-axis and the height of the WS antenna from the ground is indicated on the y-axis. We can see that sufficient signal strength will be available on the ground up to a distance of 750 m and at the first floor (5 m) up to about 900 m. The distances will increase somewhat if a significant number of buildings are lower than the skyline.

Once we reach the skyline, the signal strength is more than sufficient even at a distance of 10 km, since we have a LOS link. The LOS signal levels are indicated as a function of distance along the x-axis on the top of Figure 7.5, for convenience.

When the skyline is less than 12 - 14 m (four-storeyed buildings, or less), this means that at most an RF cable of 10 - 12 m will be needed to reach the skyline. The low-cost (LC) cable of this length will entail a loss of 5 - 6 dB, for which there is more than ample margin, given the strong signal level as one approaches the skyline.

Thus, a WS antenna can be installed outside a window at various heights all the way up to the

skyline, provided one is able to rise above the contour. If a building happens to be shorter than the skyline and it does not get NLOS coverage on its roof, one will need a pole (typically of length 2 - 6 m) on the roof to reach the skyline.

7.7.3.1 Tower Height and NLOS Coverage

The contour moves to the right as the ratio of tower height to skyline increases and to the left as the ratio decreases. As an approximate rule-of-thumb, a small change in the ratio of total tower height (from the ground) to the skyline, produces a proportionate shift in the contour. That is, a change of -10% (tower height of 12.5 m in Figure 7.5) in the ratio produces a leftward shift of around 10% (about 75 m). For larger changes, the shift is not proportional, and the contour has to be re-computed using the computer model.

7.7.3.2 Shadowing

In case there are a few tall trees higher than the skyline, they will typically cause a shadow loss of about 7 dB. In most cases one will continue to get sufficient signal above the skyline. However, if there is a large obstruction taller than the skyline (say, a big monument), there may be a region behind the obstruction that is without coverage. In most situations like this, coverage will be available from another CBS site a few kilometers away on the far side of the obstruction.

In summary, one can conclude that for tower-mounted CBS's in areas with a skyline less than four storeys high, NLOS coverage will be available typically within a radius of 1 km, provided the tower height above the skyline is at least as much as the skyline. The area beyond this can be easily covered by LOS links to the roof of the subscriber premises. Typically, one would expect to have a DIU site every 2 - 3 km in order to support sufficient subscriber density. The coverage provided by corDECT with a tower-mounted CBS is well suited for this type of deployment.

7.7.4 CBS-RBS Link

The CBS-RBS link is LOS. The total cable loss in this link is not more than 2 dB as the antennas in both cases are mounted close to the equipment. The antenna gain G_w for the RBS grid antenna is 20 dB. For the case of 12 dB sectoral antennas at the CBS, the link budget is 145 dB (113+12+20 dB, from section 7.3). The LOS path loss for a 25 km link is obtained from the LOS model of Table 7.1 as $38 + 20\log_{10}25000$, which is equal to 126 dB. A cable loss of 2 dB leaves a link margin of 17 dB.

The CBS-RBS link thus has a very large margin and the overall BER for a WS to CBS link is thus unaffected when the call goes through a RBS. It should be noted that the RBS sets up calls to the CBS on independent channels, each possibly on a different frequency. If any channel deteriorates, the call is handed over seamlessly to a better channel by the Dynamic Channel Selection (DCS) algorithm specified in DECT. There are 10 frequencies to choose from. The frequency spacing varies between 0.1% (for the adjacent channel) and 1% (10 channels away) of the carrier frequency, providing good frequency diversity to the DCS algorithm. In addition, there is antenna diversity at the CBS. Thus, the CBS-RBS link with the generous link margin is very robust to fading.

7.8 Installation and Survey Tools

The corDECT Wallset provides a simple built-in Received Signal Strength Indicator (RSSI). The signal strength is quantized with 6 dB steps and converted to a digit between one and ten, corresponding to a received power level between -93 dBm and -33 dBm. The digit is converted to an equivalent number of audio beeps, which can be heard using a DTMF telephone, by dialing a specified code. No other special instrument or meter is needed.

Thus, two beeps which indicates a nominal level of -85 dBm, is the minimum one needs for an LOS link (sensitivity of -90 dBm and fade margin of 5 dB). For an NLOS link, we would require at least three beeps (fade margin of 10 dB), though there may be one beep less at times due to fading. The number of beeps may occasionally drop even by two.

A Field Survey Tool (FST) is available, which can measure RSSI with a resolution of less than 1 dB. In addition, it can indicate a number of other interesting parameters such as Bit Error Rate, identity of the CBS it is locked to, frequency, and time slot it is using, etc. It has a visual display and a serial port for downloading measured data to a PC for off-line processing. The FST operates off a built-in rechargeable battery and is portable.

A portable CBS Emulator is also available. This transmits a DECT signal on a fixed frequency and time slot and is useful for surveying the coverage area of a potential CBS site using the Survey Tool. The CBS Emulator is self-contained and portable, obviating the need for a DIU and associated paraphernalia when conducting a survey.

7.9 Summary

In conclusion, we see that using a combination of improved receiver sensitivity, a novel timing

adjustment technique, low-cost antennas, and innovative deployment strategies, *cor*DECT provides good coverage for small, high-density areas as well as large, sparsely populated ones. It is perhaps the only WLL system providing toll-quality voice and simultaneous 35/70 kbps Internet access, while at the same time supporting a wide range of subscriber densities and coverage areas.

8.1 Introduction

corDECT provides comprehensive operation and maintenance through the *corView* OMC console. Its repertoire includes hardware and software configuration, subscriber administration, accounting, and traffic management.

This easy-to-use, menu-driven console can be run either locally or remotely. When used remotely, a single *corView* workstation can be used as a NMS for a number of corDECT systems. *corView* can also be integrated with the *CygNet* NMS to provide integrated management of a network of corDECT and other systems.

corView 100 uses the proprietary CDMP protocol to communicate with the DIU. *corView 200* and the *CygNet* NMS uses SNMP V1 or V2. In future, the TMN/Q3 protocols will also be supported.

8.2 corDECT OMC in Switch Mode

8.2.1 Configuration

The corDECT OMC provides for configuration of hardware, software and traffic routing in the corDECT system.

8.2.1.1 Sub-system Configuration

E1 Line Administration: this includes configuration of signaling, taking a line into/out of service, designation as incoming/outgoing/both.

Software Upgrade: software in the various cards in the DIU and in the CBS can be downloaded from the OMC.

8.2.1.2 System Health

The OMC continually monitors the health of the sub-systems and cards in the corDECT system. Any failure is indicated on the *corView* console and may also result in an audio alarm. The following are monitored:

- i. health of all DIU cards
- ii. health of E1 interfaces, tested through answering circuits
- iii. health of CBS lines and CBS's
- iv. health of BSD's
- v. silent polling of Wallsets, without disturbing the subscriber, to determine Wallset health, including battery voltage

8.2.1.3 Numbering Plan and Call Routing

Each DIU can be configured with one or two exchange prefixes. Each subscriber is assigned a number within one of these prefixes. *corView 200* GUI for configuring the DIU is shown in Figure 3.12 of Chapter 3.

The DIU performs digit analysis on incoming calls to determine in which of four directions the call should go: STD/ISD (long-distance), special service, local, or outgoing. Up to eight digits are examined.

Next, the route number is determined. Each route number represents a logical group of up to 48 physical ports for the purpose of physical routing and charging. Up to 1024 route numbers can be defined.

The digit analysis also determines the access level of the call. Up to 32 access levels can be

defined and for each subscriber, certain access levels can be restricted.

8.2.2 Subscriber Administration

Service class, malicious call tracing, addition to hunt group, and other subscriber features can be administered from the OMC.

8.2.2.1 Registration and Authentication

The Wallset (WS) must be registered with the DIU before it can make/receive calls through that DIU.

8.2.3 Supplementary Services

The corDECT system supports a number of supplementary services. The operator can program the system to measure the usage of each service by each subscriber.

Automatic Alarm Call: rings the subscriber's telephone at a registered time, daily or occasional.

Call Completion Supplementary Services: Absent Subscriber, Do Not Disturb, Call Queueing, and Dual Telephone Number services are present as part of this service. These services complete the call even in case calls could not be terminated at the called subscriber's end.

Call Offering Supplementary Services: Call Diversion on No Reply, Busy, and Unconditional are available as part of this service.

Call Restriction Supplementary Services: these services offer restrictions on calls made and received by the subscriber for outgoing calls, incoming calls, and dynamic barring of calls. This could be subscriber controlled or administrator controlled.

Charging: printed Call Detail Record (CDR) of any call(s) on demand. Provides battery reversal and 12/16 kHz metering pulses by the Wallset for CCB pay-phones.

Multi-party: three-party conference calling.

Rapid Call-setup: abbreviated dialing; fixed destination on time-out after going off-hook (hot-line number).

8.2.4 Charging and Billing

The corDECT system when used in the Switch Mode provides complete and flexible support for charging and billing of individual calls.

Charge Calendar: this specifies the charge rate (in units of tens of milliseconds) based on time of day, day in the year, and mode of the call (whether local or long-distance). A number of different charge calendars can be defined and associated with each outgoing route.

Call Duration Metering: if the DIU is connected to an exchange and the exchange provides metering pulses, these are used for call duration metering. Otherwise, the DIU has its own timer for each call. The time is stored in the call duration records with a resolution of one second.

Billing Support: corDECT can maintain up to 32 meters for each subscriber. The first meter contains the total pulse count. The remaining meters can be programmed to count pulses for calls based on route code. For example, one meter could be dedicated to national long-distance (STD) calls, while another could be used for international long-distance (ISD) calls.

When used as part of a larger network, the billing files can be exported to the central billing centre. This can be done in any of the following ways:

- i. tape or floppy disk
- ii. FTP over TCP/IP to the Billing Centre.

Any IP network can be used, including:

- i. an X.25 connection
- ii. a dial-up connection with PPP
- iii. Ethernet

The screenshot shows the BlueBill GUI with the following data tables:

| Line ID | Date | Time | Duration | Rate ID | Charge |
|------------|----------|----------|----------|---------|--------|
| 13076/2000 | 09/08/07 | 09:00:00 | 00:02:00 | 4007 01 | 70.24 |
| 13076/2000 | 09/04/07 | 01:12:00 | 00:04:00 | 4007 01 | 80.24 |
| 13076/2000 | 11/07/04 | 01:20:47 | 00:04:00 | 3947 07 | 41.80 |
| 13076/2000 | 11/08/06 | 00:02:00 | 00:02:00 | 19 03 | 1.08 |

| Account | Type | Usage | Charge | Start Date | End Date |
|---------|------|---------|--------|------------|------------|
| 13076 | COB | 1197960 | 831900 | 01/01/2000 | 31/12/2000 |
| 13076 | SA7 | 1197960 | 831900 | 01/01/2000 | 31/12/2000 |
| 13076 | COB | 80000 | 588.23 | 01/01/2000 | 31/12/2000 |
| 13076 | SA7 | 7904 | 4.24 | 01/01/2000 | 31/12/2000 |
| 13076 | COB | 31434 | 2187.8 | 01/01/2000 | 31/12/2000 |
| 13076 | SA7 | 3061 | 0.00 | 01/01/2000 | 31/12/2000 |

| Account | CONNECTIONS | CONNECTIONS | CHARGES | CHARGES |
|---------|-------------|-------------|---------|---------|
| 13076 | 282728 | 282728 | 28944 | 14.53 |
| 13076 | 393371 | 2706.24 | 29723 | 13.45 |
| 13076 | 118711 | 826.40 | 11175 | 2.48 |
| 13076 | 374084 | 2874.56 | 42003 | 24.19 |
| 13076 | 2300 | 19.28 | 206 | 0.81 |
| 13076 | 474976 | 2230.44 | 19420 | 26.71 |

Figure 8.1 BlueBill GUI showing detailed monthly bill

When the corDECT system is used as a stand-alone switch, for example by a Group PBX operator, the *BlueBill* software developed by Nilgiri Networks provides all necessary billing services for voice and Internet calls (Figure 8.1). *BlueBill* and corDECT can be used to implement a deposit scheme in which the subscriber can make calls until his/her deposit is used up.

8.2.5 Traffic

The corDECT system maintains a number of traffic statistics. These include Erlangs, call attempts, call success, call failure with a breakup of various causes of failures, and CPU utilization.

These statistics can be maintained for each subscriber, for each CBS, for each call type (incoming, outgoing, special service), and for each PSTN port. The DIU can be programmed to collect the statistics periodically or on demand.

8.2.6 Miscellaneous

The following services are also available:

Malicious Call Identification: record the calling number/junctor and not allow calling party disconnect.

PSTN/Subscriber Line Supervision: any PSTN port or subscriber line can be put under supervision for outgoing or incoming calls for

analysis of problems. Details of all calls are logged in a text file.

Ring-back: subscriber-initiated, to check telephone.

Operator Trunk-offer: operator can cut into a call in progress.

Temporary Out-of-service: announcement for incoming calls, outgoing calls barred.

Hunt Group: for incoming calls.

Monitoring by Intelligence Agency: any Wallset can be configured as a Monitored Number. All activity on the Monitored Number is relayed to the Monitoring Station. Up to 10 such numbers can be monitored simultaneously.

8.3 corDECT OMC in RLU Mode

The corDECT OMC in RLU (V5.2) mode is similar to that in the Switch Mode, except that certain functions present in the switching mode are not present in the RLU mode. The OMC console is a look-alike of the easy-to-use, menu-driven console of the corDECT switching system based on *corView*.

8.3.1 Configuration

The corDECT OMC in the RLU mode provides hardware and software configuration. The

Numbering Plan and Call Routing are to be configured at the Local Exchange to which the corDECT system is interfaced.

8.3.2 Subscriber Administration

Every subscriber in the RLU must have a unique subscriber number and this need not match the telephone number (Layer 3 Address) of the subscriber. It is the Local Exchange that will provide the Layer 3 address for a RLU subscriber. There are no configurable subscriber features at the RLU, as these are provided by the Local Exchange. Similarly, supplementary services and charging and billing are not the responsibility of the corDECT system in the RLU mode.

8.3.2.1 Registration and Authentication

The WS is registered and authenticated as in the Switching Mode.

8.3.2.2 Traffic

The corDECT system in the RLU mode maintains traffic statistics as in the Switching Mode.

8.4 RAS Management

The integrated iKon RAS does the switching of IP traffic. The RAS has its own SNMP agent with a separate IP address and the *RASview* GUI for management.

8.4.1 IP Configuration

The iKon RAS has its own IP address. In addition, it assigns an IP address to each subscriber upon establishment of the PPP connection from the subscriber PC. These addresses can be assigned in several ways:

- i. one address statically assigned to each RAS port. This address can be global, or a local one masqueraded by a NAT server
- ii. one IP address statically assigned to each subscriber, stored in the RADIUS server

The IP addresses of the RADIUS and NAT servers can be changed dynamically.

8.4.2 Internet Subscriber Administration

Subscriber information is stored in a RADIUS server. The RAS acts as a client to obtain authentication and other information from this server.

8.4.3 Internet Billing

At the start and end of each session, records are written to the RADIUS server.

At the start of each session, the RAS gets the subscriber's credit (session time) from the RADIUS server. It ensures that the session does not exceed the credit.

The *BlueBill* billing software (see section 8.2.4) also computes charges and generates bills for IP usage, using the RADIUS records. Charges can be based on session time and/or IP traffic, with the provision to define a number of tariff plans and discount schedules. *BlueBill* updates the credit while computing charges soon after completion of each session.

8.4.4 Traffic

The RAS maintains packet and byte counts for each subscriber. These can be used to compute traffic rates. From the RADIUS records, the utilization of RAS ports can be computed.

8.5 corView User Interface

corView 100 runs on the console of a Linux PC in character mode. It has a command-line interface. While this is intended for experienced operators, the command-completion facility and the graphical display make it usable even for novice operators (see Figure 8.2).

corView 200 is implemented in Java and runs on X-Windows. It has a sophisticated, flexible

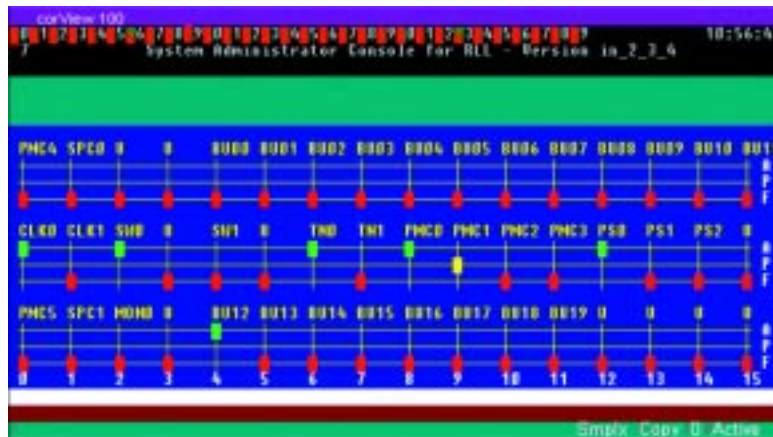


Figure 8.2 corView 100 console screen

graphical user-interface (GUI). This can be customized to the needs of different operators and includes support for local languages.

For management of the iKon RAS and IP-related configuration, *RASview* is provided. *RASview* is also implemented in Java and has a look-and-feel similar to that of *corView 200*.

8.6 NMS for Multiple DIU's

An operator with multiple corDECT systems is likely to want a Network Management System (NMS). This can be provided in several ways.

8.6.1 corView as NMS

A single workstation running either *corView 100* or *corView 200* provides remote consoles for multiple DIU's. At any time, the operator is interacting with only one of the DIU's. However at all times, the operator can see the fault status of all the DIU's. All the functions that are available at the local console are also available at the remote console.

In order to support many operators simultaneously managing a network of DIU's, *corView* is partitioned into two sub-systems. The

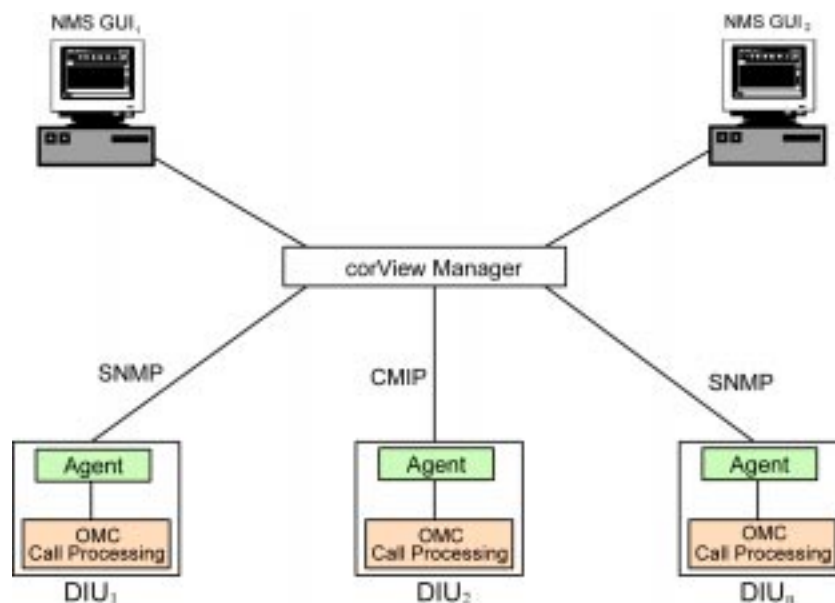


Figure 8.3 corView Manager

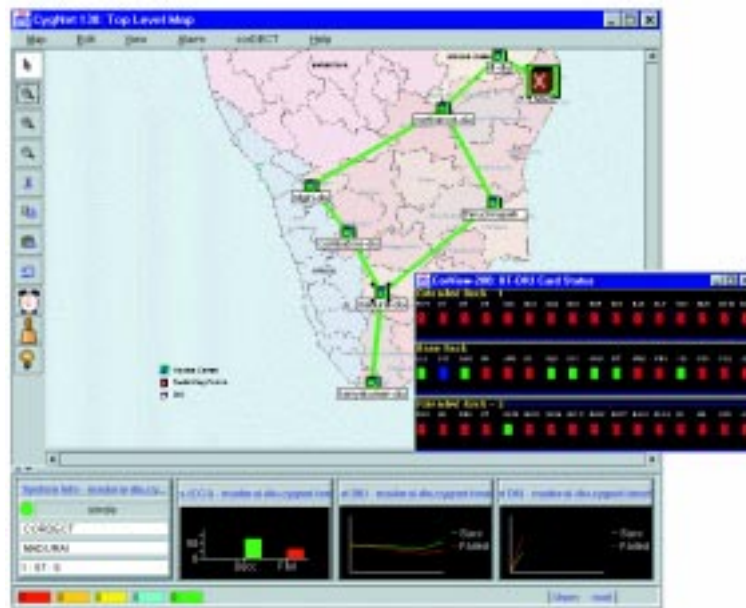


Figure 8.4 Monitoring a network of corDECT systems using CygNet

corView GUI runs on each operator workstation. All traffic between the GUI's and the agents on the DIU's is routed via a single *corView* manager (Figure 8.3) that normally resides on one of the NMS workstations.

This serves two purposes. First, it improves security and efficiency as each agent need only accept requests from one manager. Second, it simplifies the implementation of the GUI as the manager provides a high-level interface. Each GUI request to the manager may be translated into a series of SNMP requests from the manager to the agent.

This is useful when the network consists only of DIU's, or the operator has an independent management system for other network elements.

8.6.2 CygNet as NMS

The *CygNet* NMS product developed by the TeNeT Group can be used for multiple corDECT systems. *corView* and *RASview* run within *CygNet* to provide complete remote OMC functions. The operator has two options:

- i. a restricted version of *CygNet* is available which permits management only of corDECT

systems. Besides the management of individual corDECT systems using *corView*, the operator can also monitor aggregate traffic of two or more corDECT systems and can use the *CygNet* database facilities for storage of traffic and other statistics (Figure 8.4). These are useful for network analysis and planning of future growth.

- ii. the full version of *CygNet* provides the above management of corDECT systems and also integrated management of a wide variety of other telecom and Internet devices. *CygNet* provides single-point integrated management of the entire voice+Internet network.

8.6.2.1 The SNMP Agent

The corDECT SNMP Agent supports MIB-II and the proprietary corDECT MIB. This latter provides support for the full range of OMC commands. The corDECT MIB requires password-based user authentication. For protection against eavesdropping, passwords are encrypted before being transmitted on the network.

For further security, the IP addresses of legitimate managers must be configured in the agent. This can only be done through local commands.

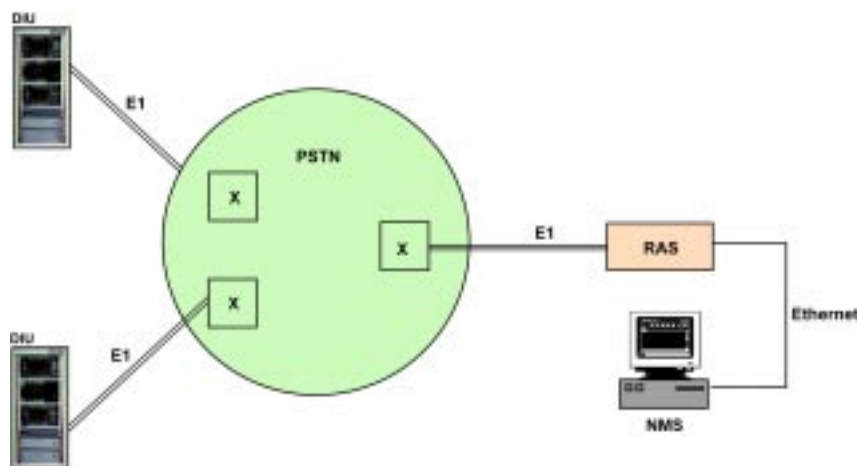


Figure 8.5 DIU's connected on independent 64 kbps leased lines to an NMS

8.6.3 Interconnections

There are several options for interconnection of one or more corDECT DIU's to a single NMS station. In all cases, the IP protocol is used over the physical links.

Single DIU

- i. Connect to a co-located NMS over Ethernet.
- ii. Connect to a remote NMS with dial-up modem, or through a 64 kbps leased line through an E1 to the PSTN

Multiple Co-located DIU's

- i. If the NMS is in the same exchange building as the DIU's, they can be connected on a single Ethernet LAN.
- ii. If the NMS is remotely located the DIU's are interconnected via an Ethernet and this Ethernet is connected to the NMS through a router, via dial-up modem, or through a leased 64 kbps line.

Remotely located DIU's

In this case, each DIU has a leased 64 kbps line (one slot on an E1 link) to the NMS location. At the NMS, all the incoming leased lines are combined into an E1. This is routed to the NMS via Ethernet by an iKon RAS (Figure 8.5).

8.7 Data Management

The OMC maintains four files related to billing. These are:

bulk.dbs: the bulk billing information for every subscriber.

normal.dbs: the Call Detail Records (CDR) of all calls.

com.dbs: the commercial information such as addition/deletion of subscribers.

tim.dbs: the record of all changes made to the system time by the operator.

The *CygNet* NMS can be configured to periodically collect various statistics related to the operation of the systems and the network.

These are stored in a R-DBMS for future use. The default R-DBMS is MySQL but this could be replaced by any SQL-92 compliant R-DBMS.

The *CygNet* NMS also maintains logs of all events such as failure of a system and voice or IP traffic crossing a threshold.

8.7.1 Redundancy

A hard disk may fail at any time. Hence, all important data, especially commercial data and historical statistics, should be stored on at least

two separate hard disks. In *cor*DECT, this redundancy can be achieved in several ways:

- i. one hard disk on each of two local OMC PC's
- ii. one hard disk on a local OMC PC and one on the NMS PC
- iii. one hard disk on the NMS PC and one on a back-up NMS PC

8.7.2 Backup

The billing and commercial databases (*.dbs) can be backed up selectively onto tape or floppy or to a local directory in the machine. Backup to a tape or a local directory can be done manually or automatically at pre-programmed times (such as specific days of the week, specific dates of the month, or every nth day).

9.1 Introduction

The corDECT system today provides a rich suite of services and features. These include simultaneous voice and Internet access at 35/70 kbps, a variety of interfaces to the PSTN including V5.2, segregation of Internet traffic bypassing the PSTN, several deployment configurations that cater to a range of teledensities from dense urban to sparse rural, modularity and scalability that make it cost-effective, and a sophisticated Network Management System. The corDECT system, however, continues to grow in capabilities. On the anvil are new products that will keep corDECT ahead of other WLL systems, as the 3G WLL system of choice for operators worldwide.

ETSI has standardized the DECT Packet Radio Service (DPRS) to enable DECT to meet 3G requirements for fixed and portable applications. DPRS leverages the high bitrate of DECT (1.152 Mbps) and its rich control-plane functionality to provide 3G services. The DECT physical layer has been upgraded to include the higher bitrates of 2.304 and 3.456 Mbps. The modulation has also been upgraded in a backward-compatible fashion so as to allow improved link budgets. DECT, with its established base and new upgrades, is thus a front-runner for cost-effective 3G fixed (i.e., WLL) applications.

The next few sections describe briefly the advanced features corDECT will provide in the near future.

9.2 Towards Always-on Internet Access

Internet access is characterized by bursts of packets with long periods of inactivity. If the corDECT Wireless Access System

wireless connection is suspended during inactive periods and resumed quickly when there is a burst of traffic, the available wireless channels can be used by a much larger number of subscribers. DECT provides for such suspension and quick resumption of connections, using its powerful control-plane signaling protocols.

Development is in progress to build this new capability into the corDECT system. When it is available, a very large fraction of the 1000 subscribers in each system can be logged onto the Internet simultaneously and remain logged on for as long as desired.

9.3 Packet-Switched High Speed Internet Downloading

It is highly desirable for a user to have the ability to download from the Internet at a high peak bitrate, even if the download-channel is shared by many users, each accessing it when needed. The bursty nature of Internet access ensures that a user can get a significant fraction of the peak bitrate whenever he needs it.

The high bitrate of the DECT air interface is eminently suited for providing this type of service. A major new development of the corDECT system underway is a packet-switched shared downlink Internet channel at 384 kbps. It will be possible for each sector in a cell to have one such shared download channel. A subscriber terminal accessing this channel picks off the data meant for itself. With this service, a subscriber will be able to download web pages and files at the peak bitrate of 384 kbps. Further, he will be sharing this fast channel only with the subscribers in the sector he belongs to.

A new subscriber terminal with a high-speed

(10BaseT/USB) data interface port is also under development to support this service.

9.4 More Integration for Cost-Effectiveness

A next-generation subscriber terminal is under development which is more integrated and compact. It will provide several options: one voice line, two voice lines, or one voice line + one Internet port. A variant of this new product that has some architectural similarity to the Multiwallset (MWS) is also on the anvil. In this product, there is an outdoor unit similar to the DTM of MWS. A small indoor unit connected to it using one copper pair provides the same three options listed above, while obviating the need for RF cabling.

9.5 New Multiwallset Developments

Under development is a MWS that will permit one to serve 8/12/16 subscribers, with blocking whenever four simultaneous calls are in progress. This will reduce the per-line cost dramatically and enable an operator to serve the hitherto unviable low-usage subscribers.

9.6 Increased Scalability

The corDECT system is unique today in the respect that the cost of the DIU, representing the up-front investment, is a small fraction of the total cost. This ensures that the per-line cost is modest even for a 250-line corDECT system. A new cost-effective, highly integrated mini-DIU will be available soon for a 50-line system and also for a 150-line system. These versions will also reduce significantly the physical infrastructure requirements for housing the DIU.

9.7 VoIP in corDECT

The corDECT system employ DSP's extensively. As there is a powerful DSP in every Wallset, the

voice signals can be converted to/from packets at the Wallset themselves, transmitted on air in packetized form and thence to the Internet through a gateway at the DIU. Thus, the corDECT system can be made VoIP-compatible in a very efficient and cost-effective manner.

9.8 New Air Interface

The new DECT air interface supports a maximum bitrate of 3.456 Mbps with fall-back options of 2.304 Mbps and 1.152 Mbps. The link budget is also better due to improved sensitivity. The new air interface enables the use of sophisticated techniques like sequence estimation and turbo-coding to achieve superior link performance.

This new air interface will enable corDECT to increase traffic capacity and Internet access speed, without increasing bandwidth and with the same types of deployment. It will also give better coverage due to the improved link budget.

This development effort is also underway. When it is available, corDECT will surpass the performance of all other 3G systems, which will typically support only 384 kbps Internet access for fixed applications and at most 2 Mbps when one is sufficiently close to the Base Stations.

9.9 Installation Planning

For planning of an access network based on corDECT and other products, the TeNeT Group will soon release *CygPlan* which will be available from Midas Communication Technologies Ltd. This GIS-based tool runs on MS-Windows and the plans are stored in an MS-Access database. Given the expected subscriber base, *CygPlan* computes the number of CBS's, DIU's and other components required, the backhaul bandwidth for voice and IP, the bill of quantities, and costs. *CygPlan* ensures that various hardware constraints are not violated. If the operator enters the building heights and other topological details of the area, *CygPlan* will predict the coverage

area of each CBS. The operator can then re-position CBS's to ensure 100% coverage of the service area. The propagation model can also use measured signal levels from a survey, where available.

9.10 Summary

The corDECT development team will continue to make available new products to take corDECT to ever higher levels of performance. At the same time, existing versions will be maintained and upgraded. This will ensure that corDECT remains the most versatile and cost-effective WLL system with the best suite of features and services.

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Appendix Digital Enhanced Cordless Telecommunications

The DECT standard proposed by the European Telecommunication Standards Institute (ETSI) is meant for providing wireless access to networks of various types, from the PSTN to LAN's. It deals only with the task of defining the air interface between subscriber terminal and Base Station. The mode of connecting the DECT-based Wireless Local Loop system to the PSTN and Internet is left to the service provider.

DECT has been specified to make possible low-cost subscriber terminals, high subscriber density with heavy call-traffic levels, wireline-quality voice, modem/fax capability, 32/64 kbps and higher-rate data services, all with a modest spectral allocation of 20 MHz. The key technical advances incorporated in DECT when compared to prior standards that make all this possible are: (i) dynamic channel selection, (ii) microcellular architecture, (iii) channels with multiple data rates and (iv) cost-effective modulation/demodulation techniques. The next two sections focus on some of the key features of the DECT standard.

A.1 DECT: Some Salient Features

- i. **Frequency Band:** The RF band originally allotted to DECT is 1880 – 1900 MHz, though the entire 20 MHz need not be employed by each system. All DECT-based systems including private and public systems operate on the common band with no requirement
- ii. **Mode of Access:** The DECT standard employs a version of Time Division Multiple Access (TDMA). There are 10 frequencies of operation in a 20 MHz band, with a spacing of 1.728 MHz. The burst-rate is 1.152 Mbps, accommodating 24 slots. The communication is Time Division Duplex (TDD). This not only ensures that propagation conditions are identical at any time in both directions of transmission, but also simplifies transceiver design. The 24 slots in a TDMA frame are divided into two groups of 12 slots each, one group for each direction of transmission. The frame structure is shown in Figure A.1. The frame duration is 10 ms and a TDD slot-pair is separated by 5 ms.
- iii. **Multi-Carrier TDMA:** A very important difference that sets DECT apart from conventional TDMA systems is that all the slots in a TDMA frame need not be transmitted on the same frequency. Each of the 12 slots could be on a different frequency, though the pair of slots used for each TDD link must be on the same frequency. This variation of TDMA is called Multi-Carrier TDMA (MC-TDMA) and is the key to the high

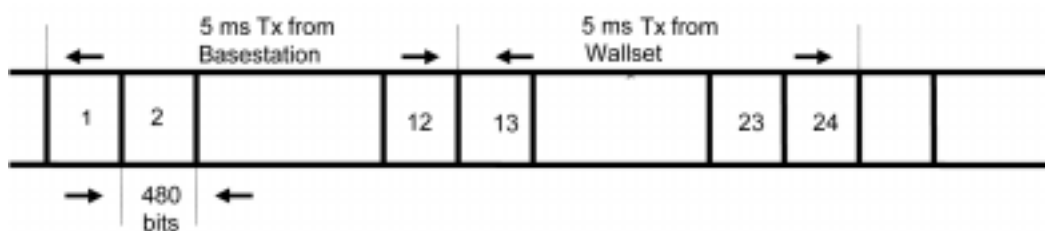


Figure A.1 DECT frame structure

capacity achieved by DECT. The 12 slot-pairs and 10 frequencies give rise to 120 channels, as if they were independent of one another. A Wallset can operate on one or more of these 120 channels, while a Base Station receives and transmits on a maximum of 12 of them at a given time. The concept of MC-TDMA is illustrated in Figure A.2 for a hypothetical frame of three slots, with each slot employing a different frequency.

- iv. **Transmit Power:** The power transmitted by Wallset or Base Station is 250 mW during the burst, or about 10 mW average power. This ties in with the need for small cells to increase frequency re-use and conserves battery power.
- v. **Voice Digitization:** DECT employs 32 kbps ADPCM. This ensures toll quality and permits all the data (fax/modem) services available from a conventional wired connection. It is also possible to occupy a double-slot to transmit at 64 kbps with error connection. This can be used for PCM or for data connectivity.
- vi. **Modulation:** DECT employs Gaussian Frequency Shift Keying (GFSK) with a Gaussian Filter (BT=0.5). Only 75% of the burst rate of 1.152 Mbps is used for voice. DECT employs ADPCM for its high voice quality and GFSK because transceiver cost is reduced. By throwing in generous signaling capacity, DECT is able to employ a very sophisticated channel selection procedure. This is the most important aspect of DECT which sets it apart from existing cellular systems and is discussed below.

- vii. **Channel Allocation:** Mobile Cellular Systems hitherto employ the so-called Fixed Channel Allocation (FCA) approach. Here, the available channels are distributed among neighboring cells in a planned fashion, depending on traffic needs. Channels are re-used at appropriate distances based on the terrain, transmit-power, antenna height, etc. Channels are allocated from the allotted set to users on demand by the Base Stations and hand-off is controlled by the network of Base Stations as the mobile user crosses over into neighboring cells.

Systems like GSM employ Mobile-Assisted Hand-Off (MAHO) but the hand-off is still centrally controlled. When deciding the re-use distance in an FCA-based system, one needs to make allowance for shadowing (due to obstructions). Re-use is decided based on worst-case scenarios, assuming the best propagation path for the interference and worst-case shadowing of the desired signal.

The DECT standard employs a completely decentralized channel allocation procedure called Dynamic Channel Selection (DCS) or Adaptive Channel Allocation (ACA). In this approach, the available set of channels is not distributed a priori among the cells. Any Wallset can set up a call on any of the channels, deciding on the one it will use at a given time by measuring the signal strength in that channel at its geographical location. The so-called received signal strength indication (RSSI) is used for this purpose. Based on a table of RSSI measurements for all channels, which is continuously updated,

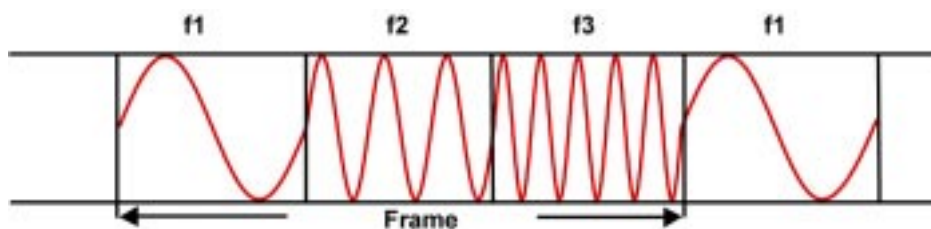


Figure A.2 MC-TDMA

the Wallset selects the strongest Base Station signal received at the given location at that time to lock onto, and the quietest channel to communicate with the Base Station. This scheme requires that Base Stations transmit some signal even if no calls are in progress, i.e., a “beacon”, or dummy bearer in DECT parlance, is a must when the Base Station is idle.

In section A.2, we take a closer look at DCS.

- viii. **Encryption and Authentication:** DECT provides encryption of the voice signal or data, to prevent eavesdropping. Authentication allows one to curb unauthorized use of the Wallset.

A.2 Dynamic Channel Selection

In a MC-TDMA system, a channel is specified by a time-slot/frequency combination. Thus, each Wallset must make RSSI measurements on each of the 10 frequencies in each time slot. There are thus 120 channels in DECT (for a 20 MHz band) to choose from. Each channel is specified by a frequency and pair of time-slots (for TDD communications). Figure A.3 depicts the available choice as a matrix. The shaded

boxes indicate channels that may be in use at a given time and place.

The time slots are synchronized to the frame of the Base Station the Wallset is currently locked to, or to a local frame clock if the Wallset is not locked to any Base Station yet. In a TDMA system, the transceiver is idle when not receiving or transmitting a burst. So, RSSI measurements can be performed in all other slots on all frequencies. With DCS, hand-over may become necessary even if the Wallset under consideration does not move, because of the autonomous decisions taken by other Wallsets. In DECT, the switch-over to another channel is made as soon as a better channel is found by RSSI measurements, without waiting for the current channel to deteriorate. The call is then simultaneously transmitted on both channels (which is easily accomplished in a TDMA system by transmitting in two slots) and a seamless switch-over is accomplished. In order to facilitate this type of self-organizing, Wallset-arbitrated hand-over, a fair amount of control information has to be transmitted between Wallsets and Base Stations. This is one reason why DECT has generous signaling capacity.

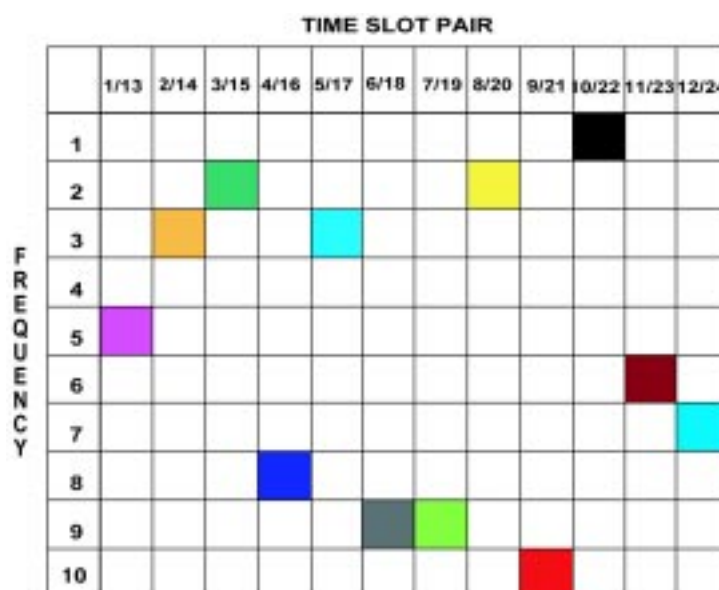


Figure A.3 120 DECT channels

The capacity gain from the use of DCS, made possible by the generous flow of control information, is enormous. Firstly, by not splitting the available set of radio channels and making the entire set available to every user, a high trunking efficiency is obtained. This refers to the ability of the system as a whole to handle statistical variations in call traffic, while still maintaining the blocking probability at the desired level. It is well known that the Erlang capacity goes up when the available radio channels are pooled. Thus, a Base Station can handle a maximum of 12 simultaneous calls without any limitations imposed by prior frequency allocation. While it would have been better to have even more slots/frame from the point of view of trunking efficiency, this also implies a higher burst rate. It is however, possible to achieve higher trunking efficiency, where needed, by co-locating multiple Base Stations with overlapping coverage areas.

A second gain from the use of DCS is that channels are re-used based on the instant situation and re-use distance can sometimes be very small. Consider the example shown in Figure A.4. The Wallsets and Base Stations are so located that either Wallset, when operating alone, could communicate with either Base Station. However, even in the situation when both are simultaneously active, it is possible for each Wallset to communicate to the Base Station nearer to it on the same channel. This is because

it is the carrier signal-to-interference (C/I) ratio that determines whether the channel is good enough. Even though the signal from the farther Wallset is good enough for communication in the absence of any other transmission on the channel, the interference that this causes to the signal from the nearer Wallset is too small to matter. Thus, a channel can be re-used even at short distances depending on the interference profile as seen by each Wallset.

Finally, Base Stations may be added to the system as and when needed to cater to increased traffic and no co-ordination or planning is needed. Indeed, multiple Base Stations can even be co-located. More than one Base Station can be reached from any location and the trunking efficiency goes up. Incidentally, DECT systems belonging to different operators, public or private, can co-exist and operate over a common frequency resource without co-ordination.

While DCS is the key to high capacity with small cells, the use of DECT in large cells with low subscriber density is not precluded. The improved sensitivity, compact antennas, and timing adjustment scheme (see Chapter 7) implemented in corDECT permit coverage up to 10 km under line-of-sight conditions. Also, the range can be extended to as much as 25 km in the case of the RBS employing high gain antennas that increase the link budget.

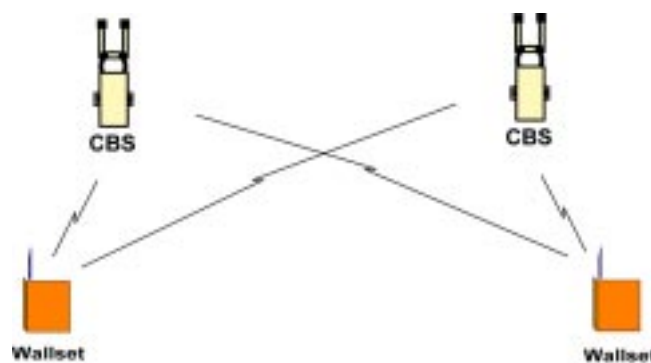


Figure A.4 Frequency re-use at short distance

In summary, DCS

- is the key to the high capacity of systems like DECT
- more than makes up for the inefficient bandwidth utilization due to other constraints
- effects channel allocation based on the actual traffic interference situations
- gives significant capacity gain when compared to other channel allocation schemes.

A.3 corDECT Physical Layer Specifications

1. RF Channel Centre Frequencies : 1897.344 - (n - m) x 1.728 MHz,
channel number n = 0, 1, ... 9
channel offset m = 0 – 21
e.g.,
m = 0 for 1880 – 1900 MHz
m = 12 for 1900 – 1920 MHz
m = 17 for 1910 – 1930 MHz
2. TDMA Frame Duration : 10 ms
3. Transmission Bitrate : 1.152 Mbps
4. TDMA Slot Length : 480 bits, with 32 bits for synchronization,
64 bits for signaling and 324 bits for voice and CRC.
A double slot of 960 bits is also defined.
5. Modulation : Gaussian Frequency Shift Keying
6. Frequency Deviation : +288 kHz (nominal) for all-ONE bit pattern -288 kHz
(nominal) for all-ZERO bit pattern
7. Transmit Power : +24 dBm nominal
8. Spurious Emission : < -8 dBm in adjacent channels
< -30 dBm, 2 channels away on either side
< -44 dBm, 3 channels away on either side
< -47 dBm in all other channels except for one
instance of -33 dBm
9. Sensitivity : at -85 dBm (typical), BER better than 10⁻⁵
at -90 dBm (typical), BER better than 10⁻³
10. Interference Performance : At -73 dBm, with a co-channel interferer at
-83 dBm, or with an adjacent channel interferer
at -60 dBm, or an interferer 2 channels away on
either side at -39 dBm, or an interferer on any other
channel at -33 dBm, BER better than 10⁻³

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Abbreviations

| | |
|--------------|----------------------------------------------------------------------------------|
| AC | Access Centre |
| ADPCM | Adaptive Differential Pulse Code Modulation |
| ARQ | Automatic Repeat Request |
| BSD | Base Station Distributor |
| CBS | Compact Base Station |
| CCB | Coin Collection Box |
| CDMA | Code Division Multiple Access |
| CSMUX | Concentrating Subscriber Mux |
| DCS | Dynamic Channel Selection |
| DECT | Digital Enhanced Cordless Telecommunications |
| DID | Direct In-Dialing |
| DIU | DECT Interface Unit |
| DPRS | DECT Packet Radio Service |
| DSL | Digital Subscriber Line |
| DSP | Digital Signal Processor |
| DTMF | Dual Tone Multi-Frequency |
| ETSI | European Telecommunication Standards Institute |
| FCA | Fixed Channel Allocation |
| FDMA | Frequency Division Multiple Access |
| FTP | File Transfer Protocol |
| GFSK | Gaussian Frequency Shift Keying |
| HDSL | High-speed Digital Subscriber Line |
| IS-95 | CDMA Cellular Standard |
| ITU-T | International Telecommunication Union - Telecommunication Standardization Sector |
| LOS | Line-of-Sight |

| | |
|----------------|------------------------------------------------------------------------|
| MC-TDMA | Multi-Carrier TDMA |
| MWS | Multiwallset |
| MWS-IP | Multiwallset with Internet Port |
| NAT | Network Address Translation |
| N-LOS | Non Line-of-Sight |
| NMS | Network Management System |
| OMC | Operation and Maintenance Console |
| PAP | Password Authentication Protocol |
| PBX | Private Branch Exchange |
| PPP | Point to Point Protocol |
| PSTN | Public Switched Telephone Network |
| RADIUS | Remote Access Dial-in User Service |
| RAS | Remote Access Switch |
| RBS | Relay Base Station |
| RLU | Remote Line Unit |
| RSSI | Received Signal Strength Indicator |
| RSU | Remote Switching Unit |
| SNMP | Simple Network Management Protocol |
| STD/ISD | Subscriber Trunk Dialing/International Subscriber Dialing |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TDD | Time Division Duplex |
| TDM | Time Division Multiplexing |
| TDMA | Time Division Multiple Access |
| V5.2 | Interface protocol for connecting an access network to a PSTN exchange |
| VoIP | Voice-over-IP |
| WAS | Wireless Access System |
| WS | Wallset |
| WS-IP | Wallset with Internet Port |