

CDMA and DECT: ALTERNATIVE WIRELESS LOCAL LOOP TECHNOLOGIES FOR DEVELOPING COUNTRIES

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Abstract—The increased importance of the telecommunications sector in the development of developing countries' economies is being realized throughout the world. In this paper, two access technologies (DECT and CDMA) are compared in the context of the requirements of a developing country such as South Africa. Factors considered are, (i) Network design and layout strategies, (ii) Access and Duplex methodologies, (iii) System Capacity and (iv) Levels of Standardization. It is shown that both technologies can be used to implement the required functionality.

Keywords—Wireless Local Loop, DECT, CDMA, Developing Countries

I. INTRODUCTION

In [1], the challenges facing telecommunications administrations are formulated as follows:

- How to satisfy ever-increasing demand to bring telephone service to every person in a country, not just urban dwellers?
- How to ensure that a country is not left behind as world telecommunications switches to digital technology?
- How to make the necessary changes in a timely fashion?
- How to meet the investment required by the introduction of new technologies?
- How to maintain order in this rapidly changing environment?

It is especially the first two points that are particularly relevant to developing countries. For instance, in 1993 the telephone density in Tanzania was only 0.37 lines per 100 people [2], and 0.49 per 100 people by mid 1995 in Ghana [5]. Also, at the end of 1994, Ghana had only about 30 pay phones in the country for international direct dialing. In South Africa, telephone densities also vary greatly. Certain communities have at least one telephone per household, whereas other communities are serviced by one or two public telephones [3].

The current interest in cellular network architectures in their various incarnations is especially interesting. In this vein, two access solutions have stirred much interest as possible candidates for access solutions in high density suburban and metropolitan areas. These are Digital European Cordless Telecommunications (DECT) [19] and Code Division Multiple Access (CDMA). Although many of the claims of the CDMA fraternity are yet to be proven in practice [20], it still remains a technology worth considering as a vehicle capable of supplying the services required by a developing country. In this pa-

per, the most commonly referred to advantages of CDMA systems over their Time Division Multiple Access (TDMA) counterparts will be analyzed, as they apply to the provision of wireless access to the local Public Switched Telephone Network (PSTN) as it is found in developing countries.

In order to compare the DECT and CDMA technologies, a standard reference base must be established. In this paper, we will work from the premise that we need to design a CDMA based access system with similar or better performance than a DECT network. Therefore, the following assumptions are made:

- Subscriber data rate - 32 kbps
- Total transmission bandwidth - 20 MHz

The remainder of the paper is organized as follows. In section 2, some network design considerations are discussed. In particular, the influence of cell size on some of the "advantages" of CDMA networks is considered. Section 3 reviews the different access and duplex methodologies used in CDMA and DECT networks, and discusses some of the regulatory issues that apply to the choice of access and duplex methodology. The attainable system capacities are evaluated in section 4, while section 5 considers the levels of standardization of both DECT and CDMA networks. Finally, some conclusions are presented in section 6.

II. NETWORK DESIGN

Two fundamental questions must be answered at the outset of the design of an access network. Firstly, what types of services must be supplied when the network is commissioned, and what migration path will be followed? Secondly, what does the subscriber distribution look like? The most fundamental requirement of an access network in a developing country is standard Plain Old Telephone Service (POTS). Above all else, *universal access* should be (and in many cases is) the prime goal of the telecommunications development policies of developing countries. This sentiment is apparent in [4], [2], [5], and should therefore also be the primary goal of an access network. This means that value added services, such as roaming, although a nicety, is definitely not a necessity. Also, any cost incurred for the provision of services other than POTS must be considered very carefully. Once a network is capable of supplying POTS, it is more important to ensure migration paths that will allow interconnectivity to other stan-

dards (eg. the interconnection of DECT and GSM networks), rather than additional services such as roaming. The advantages of this interconnectivity becomes apparent when viewed against the organization of the telecommunications network in a specific country. In the case of South Africa, fixed line services are supplied by state-owned Telkom SA Ltd., whereas GSM cellular services are provided by two private companies. Thus, if a remote community has to be supplied with basic telecommunications services, it should be possible for Telkom SA Ltd. to, for instance, install a DECT network in the community, and connect the network via the GSM cellular network to the PSTN.

Looking at the subscriber distribution, the notion of *universal access* compared to *universal service* becomes apparent. In broad terms, universal access means that every person in a country has access to a telephone, be it a community telephone or pay phone. In contrast, universal service requires a telephone line to each household. The latter being made virtually impossible to achieve in the short to medium term by the sheer number of lines that is required. For example, informal settlement areas in South Africa can have housing densities of up to 45 houses per 1000 m² [6]. Translating these subscriber densities to cell size can be done as follows: Let the number of subscribers serviced by the access network (N_{subs}) be equal to 1024 (similar to a DECT cell [11]), and assume that the penetration must be equal to 20 lines per 100 households (this would ensure easy access to a telephone for everyone in the community). Then, the total number of households in a cell will be $1024/0.2 = 5120$, occupying an area of $5120/45 \times 1000 = 113777m^2$, or a cell with a diameter of about 400 m. This would mean that the average access network can be characterized by a micro cell. Thus, one must see how DECT (essentially a pico cell system) and CDMA systems will fit into the micro-cellular mould.

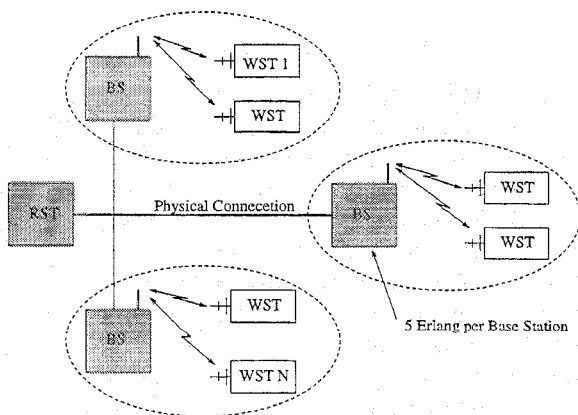


Fig. 1. Topology of a DECT network.

Being designed to service pico cells, DECT employs a three-layered network topology (see Figure 1), consisting of a Radio Station Terminal (RST), Base Stations (BS) and Wireless Subscriber Terminals (WST), although the RST and BS can be housed at a single location. However, if we know that the

access network is going to operate in a micro cellular environment, it can be assumed that there will always be a line of sight path between the transmitter and receiver. Thus, it is possible to use a two-layered network architecture from the start, thereby reducing the overall system cost (see Figure 2). Therefore, designing a tailor-made CDMA network can include this feature.

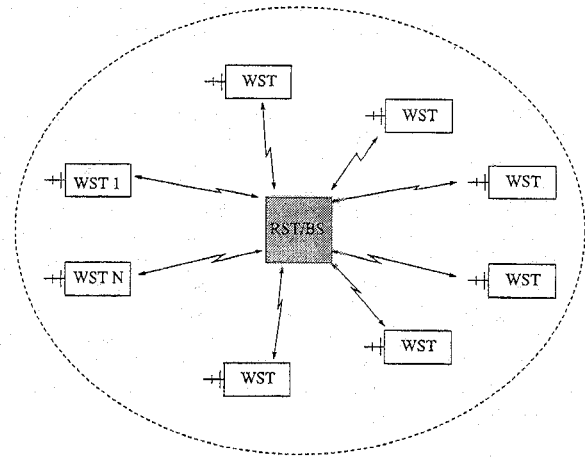


Fig. 2. Topology of a CDMA network.

One of the most frequently quoted advantages of CDMA networks, is the better propagation characteristics afforded by the wide-band nature of the transmission [7]. However, when one considers that the access networks described in this paper can be characterized as micro-cellular networks, the advantages of the increased effective transmitter power provided by the inherent processing gain of the CDMA network is negligible. Although a large portion of the cost of the system is taken up by the power amplifier, the power levels required in a micro-cellular environment is low, and the power amplifiers used by narrowband and wideband systems will have similar costs. Therefore, the slight gain in range that can be achieved with a CDMA system does not really translate into a major cost saving.

A further advantage that is also often quoted, is that multipath echoes can be resolved by a CDMA system and received by RAKE receivers [8], [9]. Assume that the micro cell has a diameter of 500 m. This means that the maximum subscriber-base station separation is 250 m. If the network has ideal power control, the received level of echoes with path lengths longer than double the maximum subscriber-base station separation would be below the minimum receive level. Assuming that an echo is received with a path length of double the maximum subscriber-base station separation, this would mean a path length difference of 250 m between the main received signal and the scattered component. This difference in path lengths translates to a $\frac{250}{3 \times 10^8} = 833ns$ delay. Using the assumption presented in section 1 of a 20 MHz transmission bandwidth and assuming Frequency Division Duplex (FDD) operation (see section 3), a RAKE receiver can resolve multipath

echoes separated by

$$T_{delay} = \frac{1}{W} \quad (1)$$

$$= \frac{1}{10 \times 10^6} \quad (2)$$

$$= 0.1 \mu s \quad (3)$$

Therefore, under the assumptions presented in the introduction, and assuming near perfect power control, a RAKE receiver will be able to recover multipath echoes only from subscribers situated at the edge of the cell, with a limited benefit to system capacity.

III. ACCESS/DUPLEX METHODOLOGY

Two completely different access methodologies are used by DECT and CDMA systems. DECT systems use Time Division Multiple Access (TDMA) as an access methodology, whereas CDMA systems use Direct Sequence Code Division Multiple Access (DS-SS-CDMA). Also, in DECT systems, transmit and receive operations are separated using a Time Division Duplex (TDD) protocol, whereas the CDMA system preferably uses a Frequency Division Duplex (FDD) scheme. Although this is not necessary, it is shown in [10] that CDMA systems exhibit a drop in capacity when using TDD. The advantage of TDD transmission, is that the same antenna can be used, without an expensive diplexer filter or circulator, for the transmission and reception of data, as these two operations are mutually exclusive. On the other hand, TDD systems require more complex synchronization between the base station and subscribers. Synchronization will prove to be very difficult, especially when the difference in transmission path lengths between the base station and different subscribers is large, or if the channel suffers from severe multipath effects. As was shown in the previous section, this is not the case.

When using a CDMA system in an FDD environment, synchronization is made easier by having continuous upstream and downstream transmissions. The same is not true for power control however. As will be shown in section 4, efficient power control and interference cancellation algorithms are necessary to yield system capacities equal or better than that of DECT. When using these techniques in conjunction with an FDD access scheme, in a scenario where the fading and attenuation of the two transmission bands are uncorrelated, sophisticated channel estimation algorithms will need to be employed either at the base or the subscriber stations. It is especially in the uplink that the power control must be tight (ie. good channel estimation), as it is this link that determines the overall system capacity. Thus, the complexity of the *near-far problem* increases if the transmit and receive bands are uncorrelated. Although the access network described in section 2 will normally ensure line-of-sight between the subscriber and base station, regulatory issues might force the transmit and receive bands to be separated by up to 100 MHz, making channel statistics uncorrelated in the two bands.

IV. SYSTEM CAPACITY

Formulating capacity requirements for modern telecommunication systems are becoming increasingly difficult. The result of the multitude of different teleservices offered in different operating scenarios, is that the teletraffic density generated will depend not only on the environment, but also on the terminal types and terminal density. In this regard, several capacity measures have been formulated, including the Equivalent Telephone Erlangs (ETE) per square kilometre and megabits per second per square kilometre (Mb/s/km²) [12]. However, as bandwidth is a very precious commodity, it needs to be included in the capacity calculation to facilitate comparisons between systems on an equal footing. Therefore, we shall use bits per second per square kilometre per hertz (bps/km²/Hz) as a measure of the capacity of an access system.

In general, the capacity of an access system can be calculated as follows:

$$\eta_s = \frac{RN_s}{B} \quad \text{bps/km}^2/\text{Hz} \quad (4)$$

where η_s denotes the capacity of the access system, R denotes the information rates in bps, N_s denotes the number of simultaneous connections at rate R per km² and B denotes the total allocated system bandwidth. If frequency re-use is employed, the sum of all allocated bandwidths and subscribers in each cell of the frequency re-use pattern must be taken.

The capacity of a DECT system is quoted to be up to 10 000 Erlang per km² [11]. Given that the information rate R is equal to 32 kbps and the allocated bandwidth equals 20 MHz, the capacity of a DECT system is then

$$\begin{aligned} \eta_s &= \frac{32 \times 10^3 \times 10000}{20 \times 10^6} \\ &= 16 \quad \text{bps/km}^2/\text{Hz} \end{aligned} \quad (5)$$

Note that the frequency re-use factor is taken as 1, as the DECT system employs automatic channel allocation.

Now assuming that a CDMA system has two 10 MHz bands available (that is FDD operation), the maximum spreading sequence length that can be used is equal to

$$N = \frac{BR_{cd}}{R} \quad (6)$$

where N denotes the spreading sequence length, B denotes the allocated bandwidth (10 MHz), R denotes the subscriber data rate (32 kbps) and R_{cd} denotes the forward error correction coding rate. It is assumed that the CDMA system will use some type of forward error correction, as this substantially increases the capacity of the system. The inclusion of forward error correction does not provide the CDMA system with an unfair advantage, as the total allocated bandwidth is the same as for the DECT system. Using eq. 6, and assuming that a half-rate convolutional code is used, the maximum spreading sequence length can be calculated as $N = 152$. The

closest practical length to $N = 152$ for a spreading sequence is $N = 127$, which yields a system capacity of 96 simultaneous channels [13], excluding the effect of co-channel interference. As a general rule of thumb, co-channel interference contributes approximately 50% [14] of the interference in a cell, yielding a capacity per cell of $K = 96 \times 0.5 \approx 48$ subscribers. A further refinement can however be made. Because CDMA systems are interference limited, limiting the amount of interference present in a cell will directly increase the capacity of the system. Thus, sectorizing each cell into 3 sectors, will increase the number of users per cell to $K = 48 \times 3 = 144$. This would mean that a total of $10000/144 \approx 70$ cells are needed in a area of one square kilometre to yield a system capacity equal to that of a DECT system. To accommodate this number of cells, a cell diameter of approximately 135 m is required. Such small cell sizes will necessitate the use of either very strict power control algorithms, or sophisticated interference cancelation or joint detection algorithms [15]. However, these techniques can be compared to equalization techniques required in TDMA systems, such as DECT, and must not be seen as a major drawback to the implementation of CDMA networks.

V. STANDARDIZATION

Probably the most powerful driving force for a new technology to gain market acceptance, specifically in developing countries, is the levels of standardization. Network operators and service providers seem reluctant to act a guinea-pigs for new technologies or standards. Therefore, if one plans to enter a market, it is of the utmost importance to ensure that the proposed product comply with as many standards as possible.

The GSM and DECT revolution that has been sweeping Europe (and nowadays the whole world!), has been driven to a large extent by the standardization of various interfaces. This standardization process has in general been completed before the technology has been introduced into the market, leveling the playing field for all manufacturers to compete on an equal footing, generating high levels of competition and lowering prices. Driven by this standardization process, we are currently seeing the GSM and DECT technologies merging with the definition of standard interfaces to base station controllers¹ [11]. The ultimate aim of this process being the establishment of DECT networks covering roaming individuals in high density areas (pico/micro cells), and GSM networks connecting mobile individuals (macro cells) to the PSTN. The main advantage of this process, is that huge markets are opening for DECT and GSM systems². Now, although the DECT technology includes more features than needed for local access networks, the price of the core technologies of DECT systems is extremely low, making it still more cost effective to install DECT networks than other

competing technologies like CDMA.

In contrast with DECT and GSM systems, CDMA based wireless communication systems have not seen the same levels of standardization. At this stage, the main CDMA standard is the IS-95 mobile CDMA standard, with systems such as OMNI POINT also using CDMA technology [17]. However, two main disadvantages of the IS-95 standard (and systems based on it like QCTEL³) remain. Firstly, the standard was formulated without the wide consultation process that applied to GSM and DECT. This means that the cross-pollination between countries from which GSM and DECT have benefited is not present in the IS-95 standard. Furthermore, this standard was written from an American point of view, and might run into difficulties when applied outside the USA. For instance, IS-95 based systems operate in 1.25 MHz bands. This choice of operating bandwidth was done to fit into the spectrum in the USA. Already with DECT systems, bandwidths of 20 MHz are available and CDMA systems can exploit this larger bandwidth better than any other access technology.

The second main disadvantage is more technical, and lies in the absence of measures eliminating adjacent and co-channel interference. Several papers have been written outlining the capacity advantages that can be gained by employing joint detection and interference cancelation algorithms [18].

With the mentioned points in mind, it is probable that the IS-95 standard will at most be an interim standard, and will see major changes before it gains wide acceptance outside the USA. In this matter, it will be necessary for the new standard to include inputs from the USA, Europe, Japan and, as far as WLL applications go, from developing countries. Consequently, it might still be some time before CDMA based systems can gain the same cost advantages that DECT and GSM has from standardization.

A. Conclusions

Choosing to back a single technology in today's fast changing world is probably the worst decision that can be made. New approaches are emerging daily, and we are starting to see the hybridization of existing techniques more and more.

It would seem that a situation is emerging where more than one technology can fulfill a certain role. From the discussions in this paper, it should be apparent that both DECT access networks and CDMA based access networks can be employed in developing countries to provide telephony service in areas with high subscriber densities; each having its own pros and cons. Thus, when it comes down to the final decision on the a suitable technology to use, the features embodied in a specific product, rather than the underlying technology might be the key factors considered by service providers. Here it is especially interconnectivity that might prove to be the most important factor. The easier it is for a service provider

¹A good example is the so-called A-interface

²In [16] the market for DECT lines in Italy is estimated to be greater than 20 million lines

³The RLL system from Qualcomm

to integrate a new product (read also technology) into its existing network, the more market acceptance it will gain. Also, many social factors such as the method of billing, the availability of power sources and the general perception of the technology used play a major role in the selection of a specific technology by an operator in a developing country. For instance, in many areas in South Africa people do not have postal addresses or electric power.

To conclude, it would seem that the choice of backing either CDMA or TDMA as an access technology no longer exists. Rather, products incorporating both technologies must be included in a product range, and interconnectivity between these products must be ensured.

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