Cordless Personal Communications

Digital cordless technology is not only the wave of the future; digital standards are being translated into products today.

Dr. Walter H. W. Tuttlebee

WALTER H. W. TUTTLEBEE develops and manages a range of mobile and personal communications R&D activities at Roke Manor Research, Romsey, Hampshire, UK.

Digital cordless telephony is no longer a thing of the future. After a decade of research and development, technical standards are being translated into products and commercially viable networks. This article addresses the role of digital cordless technology in the transition to the personal communications system (PCS) era. Although this role cannot be predicted with certainty — markets will make their own decisions — we can identify a range of technical, service, implementation, and market issues that will influence it.

This discussion is limited to digital cordless systems. Although analogue cordless systems, CT1, are already in widespread usage and still undergoing significant developments and enhancements, digital technology is the wave of the future. This article focuses on developments in Europe, where the development of cordless standards was pioneered. Advanced microcellular radio technologies are also being explored in North America and Japan, but Europe remains unique in having established accepted standards to facilitate volume markets.[1]

Because PCS, personal communications networks (PCN), and cordless access have been subject to widely differing perceptions, this article includes a review of the evolution of the pan-European digital cordless standards, as well as a brief summary of these standards — CT2 and DECT — and a description of industry progress in equipment availability and service implementation. The conventional European model of the digital cordless telephony marketplace has envisaged three overlapping applications — domestic, business, and public access (Telepoint). A discussion of this model and the progress to date in addressing each of these applications is also included.

Wireless data networking has emerged as a new opportunity of the 1990s — European cordless standards were designed with such needs in mind, and cordless LAN products to the DECT standard have already been announced. This article presents a view of the role of CT2 and DECT technology for such applications and the implications for cordless integrated services.

Finally, this article looks beyond today's technology at current European activities to standardize a Universal Mobile Telecommunication System (UMTS), ITU activities on Future Public Land Mobile Telecommunication Systems (FPLMTS), and possible scenarios for the role of cordless technology over the next decade.

Pan-European Digital Cordless Standards

European research into digital cordless telephony, which laid the foundations for today's products, began in the UK and Sweden in the early 1980s. Recognition of the limitations of the contemporary analog products, in terms of security and user density, and the market potential of wireless PABX, WPABX, were key factors stimulating this early activity. Rapid technology advances fueling, and fueled by, the growth in the cellular radio market over the decade, again particularly in the UK and Scandinavia, supported implementation feasibility whilst also helping to direct development toward higher radio frequency digital solutions. A timeline of European digital cordless development is illustrated in Fig. 1.

In 1985, CEPT initiated standardization of second-generation cordless telephones. By this time, several companies had developments in hand, and the first digital cordless standards were published in the UK in 1987. These national standards specified parameters associated with the operating frequency, transmitter power and spectrum, and interconnection with the PSTN, but left the issues of radio protocols open to manufacturers — these were coexistence rather than common interface specifications. European debate over the relative merits of different technical solutions was underway by this time, with Sweden advocating a TDMA/TDD solution in contrast to the UK's FDMA/TDD. Demonstrations of prototype equipment operating at about 900 MHz were given in Autumn 1987 to CEPT. The stalemate between the two approaches resulted in a CEPT decision in January 1988 to base the new European stan-

[1] *A comprehensive description of the commercial background, technical foundations, and technical standards of European cordless technology is contained in reference [1].*

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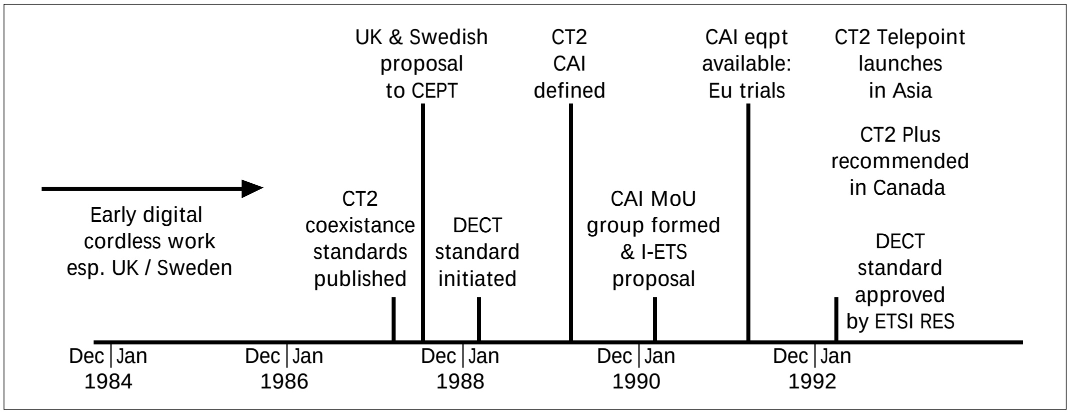


■ Figure 1. *Cordless timeline diagram.*

dard upon a TDMA/TDD/MC (Time-Division Multiple Access/Time Division Duplex/Multiple Carrier) approach operating just below 2 GHz, henceforth to be known as the Digital European Cordless Telephony (DECT). "Telecommunications" replaced "Telephony" in 1989, an acknowledgement that DECT should support data as well as voice communications.

With the formation in 1988 of the European Telecommunications Standards Institute (ETSI), responsibility for DECT standardization transferred to the ETSI RES 3 (Radio Equipment and Systems) subcommittee. Several working groups and a full-time project team were established, with the full technical details of the DECT standard completed on schedule by mid-1991. This was followed by a public inquiry phase during the latter half of 1991 and formal approval of the specifications by the ETSI Technical Assembly in March 1992. Following the normal voting procedures, DECT became a European Telecommunication Standard, ETS 300-175, in August 1992. DECT has a guaranteed pan-European frequency allocation, supported by ETSI member administrations and enforced by European Commission Directive 91/287.

In the late 1980s, manufacturers that recognized the potential importance of pan-European standards from ETSI chose to support DECT standardization while completing their existing developments, seeing these as near-market products by comparison. This led to the parallel developments of CT2 in the UK and of CT3 (also known as DCT900 or BCT900) in Sweden.

Because the early UK standards were designed as coexistence standards, several proprietary products were developed. In 1989 the UK government issued four operator licenses to allow public-access cordless, generically known as Telepoint. As part of the license conditions, operators were required in due course to allow roaming between systems, thereby implying the need to adopt common radio protocols — a common air interface, or CAI. A CAI specification had been developed cooperatively by UK manufacturers during late 1988 and was published in May 1989 after a series of consultations with other European PTTs and industry. With the emergence of the CT2 CAI standard, some manufacturers chose to abandon their prior developments and move straight to CAI equipment, while others chose to complete and market proprietary products such as Shaye Communications' Forum Phone and Ferranti's Zonephone.

Since the initial publication of the UK CAI standard, it has been adopted by ETSI and exists alongside DECT as a European standard, having received endorsement as I-ETS 300 131 in November 1991. It has also received widespread international support, for Telepoint applications in particular, as described below.[2] The CT2 CAI MoU group, formed in 1990 played an important role in promoting the acceptance of a common Telepoint service and in providing the common network and inter-service agreements lacking in the CAI air interface standard. This group has developed into a truly international organization far beyond its European origins and is now known as the Association of International Telepoint Operators.

When Telepoint licenses were announced, the UK government also launched the concept of PCN. Some industry viewpoints on making personal communications accessible to the masses were that PCN should provide universal geographical coverage with two-way calling, be small, convenient and inexpensive. These concepts were not new — the idea of a convergence between cellular and cordless telephony for the mass market was already under investigation within the European Community-funded RACE program.[3] This initiative served to accelerate the development time frame. Initial proposals for UK PCN envisaged the use of both cordless (CT2, DECT) and cellular (GSM) standards to provide such a capability, but the winners of network licenses eventually migrated towards a GSM-based standard, enhanced to operate at 1.8 GHz, now known as DCS1800.[4] The DECT standard has been specified to include a role as an access extension to GSM — thus, the possibility of using a cordless terminal to access PCN networks still exists in principle.

Cordless Technology

In contrast to cellular radio, cordless standards primarily offer an access technology rather than fully specified networks.[5] Cordless terminals generally transmit at lower power than cellular, necessitating the use of microcells with a range of 100 meters or so, compared to cell sizes of tens of kilometers for cellphones. In high-density offices, much smaller cells, picocells, may be used, with the systems operating in an interference-limited rather than range-limited mode — in such a scenario traffic densities significantly higher than those available from cellular standards may be achieved, on the order of 10,000 Erlangs/sq km. The CT2 and DECT

[2]In Sweden, Ericsson continued development of their CT3 system but failed to secure ETSI endorsement. Attempts to secure its acceptance as a standard for the Canadian market were unsuccessful.

[3]Early work in the mid-1980s in the EC RACE program led to the concept of a Universal Mobile Telecommunications System — UMTS. The initial RACE program in this area was completed in June 1992. Having laid a foundation, this work is now undergoing further development in several other collaborative research programs under RACE 2, the second phase of RACE.

[4]Further details on DCS 1800 are given in the article by Robin Potter of Mercury Personal Communications elsewhere in this issue.

[5]The DECT standard offers a proposed network architecture in addition to the air interface physical specification and protocols, but without specifying all of the necessary procedures and facilities.

DECT's use of multiple timeslots dictates a higher transmission data rate than for CT2, and thus a wider transmitted bandwidth and associated carrier spacing.

PARAMETERS	CT2 CAI	DECT
Operating Frequency	864.1-868.1 MHz (Europe)	5 mW
Radio Carrier Spacing	100 kHz	
Transmitted Data Rate	72 kb/s	
Channel Assignment Method	DCA	
Speech Data Rate	32 kb/s	
Speech Coding Technique	ADPCM G.721	
Control Channels	In-call-embedded (traffic channel used for initial call set-up)	
In-call Control Channel Data Rate	MUX1.2 0.75 kb/s (plus 0.25 kb/s CRC) OR MUX1.4 1.5 kb/s (plus 0.5 kb/s CRC)	
Total Channel Data Rate	33/34 kb/s	
Duplexing Technique	TDD	
Multiple Access-TDMA	Single TDD timeslot	
Carrier Usage-FDMA/MC	40 carriers	
Bits per TDMA Timeslot (speech/data+embedded control)	66/68 bits	
Timeslot duration (including guard time)	1 µs	
TDMA frame period	Not applicable	
Modulation Technique	Gaussian Filtered FSK	
Modulation Index	0.4 to 0.7	
Peak Output Power	10 mW	
Mean Output Power		

■ Table 1. *DECT and CT2 CAI standard parameters.*

standards have many similarities and some important differences. Their principal radio characteristics are summarized in Table 1.

The dynamic channel assignment (DCA) technique employed in cordless systems automatically provides adaptive channel reuse, obviating the need for the expensive cell frequency planning normally associated with cellular radio systems. With DCA (free channel search) the handset and base station together self-select a suitable channel to support new traffic requirements, based upon radio channel availability measurements at both ends of the link. Such an approach indeed is essential for the high-density office WPABX environment and is increasingly being considered for wider PCS applications because it offers simpler system deployment. The use of DCA results in an interaction between different cordless links such that the performance of a cordless system must be derived from modeling or analyzing the system as a whole, rather than simply considering a link in isolation from its dynamically changing radio environment. Several such simulations for CT2 and DECT have been published [2-4].

Both standards use 32 kb/s ADPCM speech coding, low transmitter power, and time-division duplexing, transmitting, and receiving on the same frequency channel. CT2 maps a single time-division duplexed telephone conversation onto a single frequency channel; DECT employs a more complex time-division multiple access, 24-timeslot scheme. Thus, a single DECT carrier can support multiple calls over a single RF transceiver. An important feature of the DECT frame structure is the ability to employ multiple timeslots to support higher data rate links — for example, ISDN services. Occupied DECT timeslots can change carrier frequency even within a single frame, providing added system flexibility. The differing frame structures are illustrated in Fig. 2a and 2b.

DECT's use of multiple timeslots dictates a higher transmission data rate than for CT2, and thus a wider transmitted bandwidth and associated carrier spacing. Current European specifications allow for 40 carriers spaced by 100 kHz and located in the 864.1-868.1 MHz band for CT2, and for 10 carriers spaced by 1.728 MHz and located in the 1880-1900 MHz band for DECT. A possible extension of the DECT band by a further 30 MHz has been discussed and may occur if demand materializes. The presence of existing allocations outside of Europe means that alternative frequency allocations will be used in some countries (such as Australia and Canada) for CT2, although still within the 800 to 900 MHz range. More detail on the operation of the DECT and CT2 systems is available in [1] and [5], as well as in the standards publications themselves, which are available from ETSI.

Applications of Cordless Access

Perceptions of the anticipated digital cordless telephone market during the mid-1980s differed across Europe. The shortcomings of existing analog domestic telephones in terms of security, privacy, and user density were appreciated, and this was the initial driver in the UK. Elsewhere, the potential of cordless access to permit user roaming in business applications was the key driver. In addition, the opportunity to offer a public-access Telepoint service was quickly recognized — the technical implications of which, in terms of a common radio interface, have already been noted.

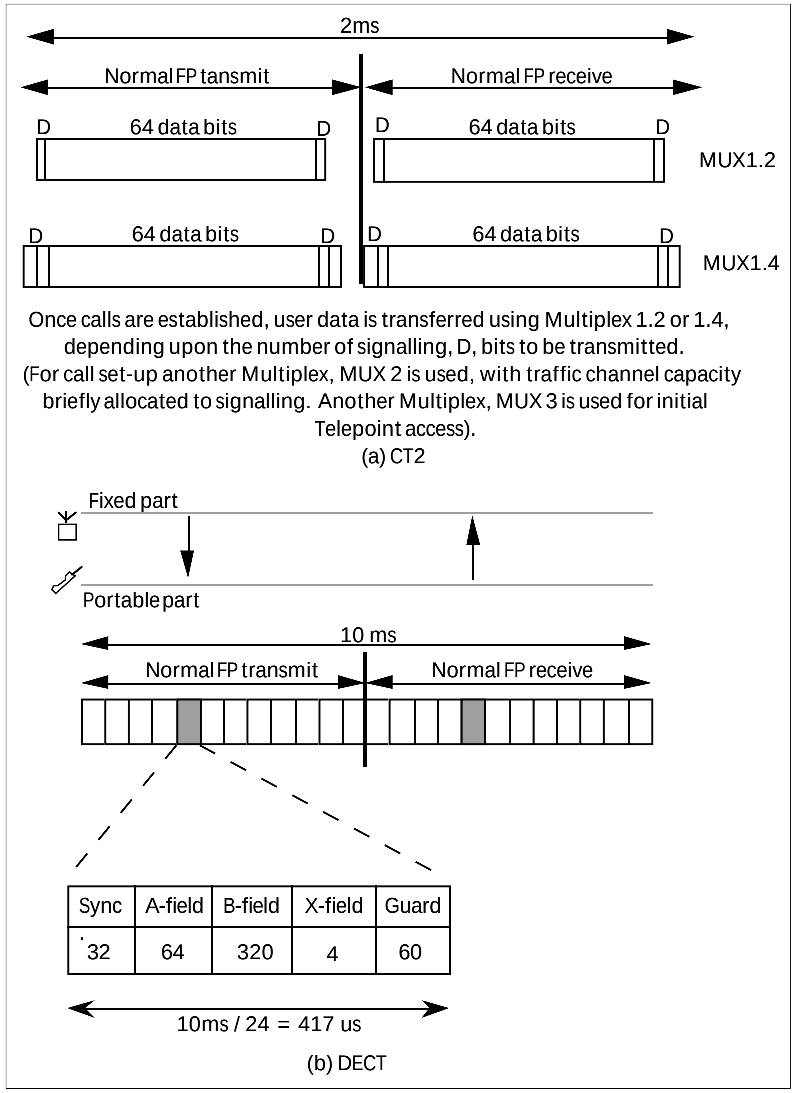
The possibility of using a single cordless telephone instrument in all three environments was seized upon as providing a significant additional user benefit that could enable each of these three markets to stimulate the growth of the others. Several manufacturers commissioned research into the anticipated market sizes and interdependences. Results from one such study are shown in Figure 3, which displays a forecast for the application share for CT2 some five years after product launch. Such a figure displays a static snapshot in time — clearly the domestic, Telepoint, and business markets will not grow at the same rate and indeed each will be impacted by differing factors. Furthermore, the role of cordless technology for the local loop is an additional emerging "wildcard" market that was not envisaged at the time.

The Domestic Application

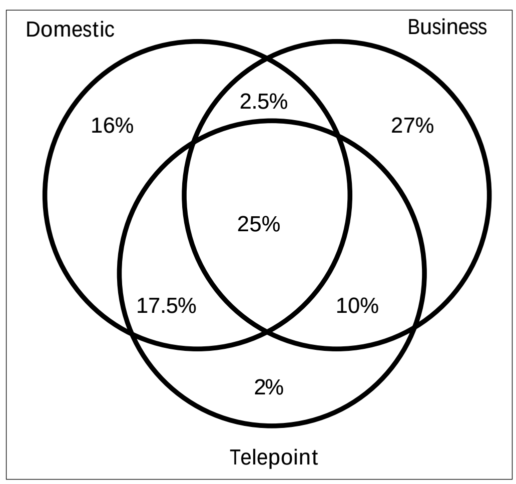
A key factor affecting market penetration of any new product is price and, in particular, price relative to existing comparative products. Within the UK, existing analog cordless telephones built to a simpler technical specification than elsewhere in Europe have been sold. Therefore, the relative price competitiveness of the new digital products in the UK is poor compared with mainland Europe. For this reason, UK CT2 manufacturers have not yet significantly targeted the domestic market, concentrating instead initially upon the Telepoint and the business WPABX markets — domestic base stations are being sold, but primarily as part of a Telepoint package. Given the ability of the business market to bear the higher prices usually associated with the early stages of the product life cycle a similar approach would seem likely as DECT products become available. As product volumes increase and prices drop, the new digital cordless phones will become increasingly competitive for domestic applications, given also the additional attraction of Telepoint usage as the service becomes better understood.

Telepoint

Although it is a European concept, the initial success of Telepoint has been in Asia, where early systems have taken off remarkably, in spite of the absence of the complementary domestic and WPABX products. Singapore Telecom launched its commercial Telepoint network to the CT2 CAI standard in January 1992. A total of 1500 handsets were sold on the first day and some 10,000 subscribers, two thirds of the operator's first year forecast, were added to the network within the first month of opera-



■ Figure 2. *Structures of CT2 and DECT.*



Country	System Name	Status	Characteristics	Operator
France	"Bibop"	Strasbourg Trial Commercial Service expected in Paris, September '92.	Trial provided full coverage with 300 base stations and 3000 handsets with two-way calling.	France Telecom
Germany	"Birdie"	Munich Trial Commercial Service decision expected October 1992.	Approximately 3000 trial users, trial extended to Kehl, near Strasbourg, to allow international roaming with the BiBop system.	DBP Telekom (possible second operator)
Netherlands	"Greenpoint"	Commercial service began May 1992.	National coverage including 350 basestations in Amsterdam, plus coverage of stations, airport, post offices, etc. (2000 base stations planned); handsets with built-in pagers planned.	PTT Netherlands (possible second operator "Bluepoint")
Finland	"Pointer"	Helsinki Trial Began June 1992; commercial Service expected Autumn 1992.	Cheaper than payphone charges; coverage of Helsinki and other major cities and transportation routes (500 base stations at launch, expanding to 2000).	Telecom Finland
UK	"Rabbit"	Commercial Service began May 1992.	National coverage, with 12,000 base stations expected by December 1992; paging and voice mail options.	Hutchison
Hong Kong		Commercial Service began March 1992.	Full coverage, use with paging 33,000 subscribers by June 1992.	Two operators: Hutchison and Chevalier
Singapore	"Callzone"	Commercial Service	Full coverage, (2300 basestations at	Singapore Telecom

■ Table 2. *Status of CT2 CAI Telepoint networks [7, 8].*

tion. In Hong Kong, where a full coverage system combined with paging has been installed, the system rapidly sold out, with 20,000 subscribers within the first month. In both cases the systems have used the CT2 CAI standard with readily available equipment. Recent market forecasts suggest some 2.3 million Telepoint subscribers in the Asia-Pacific marketplace over the next decade [6]. Like the initial UK networks, these early Asian ones support only outgoing calls from the Telepoint user — however, the high penetration of pagers in these countries perhaps reduces the perceived importance of this initial limitation. Elsewhere in Asia, Thailand launched its CT2 Telepoint system in February 1992. Malaysia has adopted CT2, and the People's Republic of China plans to implement a system in Shenzhen, Guangdong province, during 1992.

Such success contrasts with the earlier UK experience during 1989-1990 in which three commercial Telepoint systems were launched based upon proprietary (non-CAI) CT2 standard equipment. These three competing networks failed to attract a significant user base and all subsequently closed down. The demise of these initial networks has been attributed to the lack of a common standard, limited supplies of handsets and base stations, and high equipment prices and service charges. The lack of any significant incentive to develop the complementary domestic and WPABX markets, which was partly due to the lack of available product, has also been cited as a contributory factor — although this may be questioned in the light of the experiences in Asia.

A fourth UK network operator licensed at the same time as the other three, Hutchison Telecom, chose to await the ready availability of standardized CT2 CAI equipment. Hutchison launched its network in mid-1992, initially supporting only outgoing calls but offering paging and messaging facilities as standard options. This followed a prolonged trial with 1000 users and 2000 base stations located across the UK. The purpose of the trial was to test and validate the network infrastructure and software and, equally importantly, to establish end-user feedback. The orientation of the Hutchison system is unashamedly consumer/market led, with the nontechnical brand name Rabbit in contrast to the technically derived names of the earlier systems. Hutchison believes that the careful planning and willingness to wait for the necessary factors to stabilize (standards and equipment availability) prior to launching its system will pay off.

Hutchison's first commercial service was launched in the Greater Manchester area in May 1992 and provided full coverage in the city center area. The launch was followed by a rapid rollout across the north of England during the summer. National coverage was in place by autumn, and 12,000 base stations are scheduled to be in place by the end of the year. Initial reports at the time of this writing indicate that sales in the Manchester area exceeded expectations.

Elsewhere in Europe, other CT2 CAI Telepoint networks either have been in trials, are being commercially implemented, or are planned (Table 2). Some 14 countries have now signed the European Telepoint Operators Memorandum of Understanding, and three additional signatories are expected shortly. In France, user interest was such that the size of the Strasbourg "Bibop" trial was increased from a planned 2000 to 3000 handsets. Base stations have also been deployed in Kehl, just across the German border, in order to investigate the potential of cross-border roaming.

Commercial operation in France with 1500 base stations covering the center of Paris is expected as of this writing by September 1992. A further 4000 base stations are planned to extend coverage to the Ile-de-France area, a 30 to 50 kilometer radius around Paris that contains 25 percent of France's population. Two-way calling was seen from an early stage as important in France, so an automatic local log-on capability has been built into the French trial network. Such capabilities are likely to be adopted more widely across Europe, along with intersystem roaming, in the coming years.

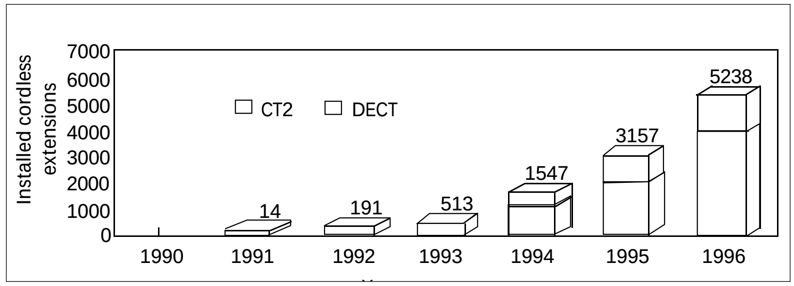
In North America, the Radio Advisory Board of Canada recommended adoption of a CT2-based Telepoint system,[6] a decision endorsed by the Canadian government in May 1992. Operating licenses are expected to be awarded in late 1992 or early 1993. In the USA, although the demand for cordless access is high, the proliferation of technical innovations for implementing personal communication services, fostered by a very competitive standards environment, makes any kind of prediction about the likely role for CT2 Telepoint difficult. Having said this, trial CT2 Telepoint systems are operational under experimental FCC licenses. In South America, Brazil has adopted the CT2 CAI standard with a slight shift in frequency band. Other countries showing interest in CT2 Telepoint include several other European and Asian countries, as well as South Africa, New Zealand, Australia, and Indonesia.

Although CT2 is the first available Telepoint standard, DECT has also been specified to support public access. In reality, and given development and implementation time frames seen for CT2 in recent years, it is too early to say what relative roles CT2 and DECT will eventually find for public cordless access. CT2 proponents would argue that by the time DECT equipment becomes available, CT2 will be firmly established in Telepoint. This, however, makes certain assumptions for development time frames of DECT equipment and does not consider interactions between the different application markets — domestic, public, and business — or cultural and geographical preferences. The relative roles of DECT and CT2 products in the emerging business WPABX market may also have an impact upon this, as will relative product pricing.

Wireless PABXs

The potential business applications of cordless telephones were one of the early drivers for the development of the technology. While early European cordless products focussed upon Telepoint, the past year has seen significant progress in the WPABX arena with, notably, the launch of systems from GPT, Northern Telecom, and others. Forecasts for the cordless business market continue to predict considerable potential for such CT2 based systems, as well as for DECT systems when these become available (Fig. 4).

Cordless access in the PABX environment offers two key sets of benefits. First, it enables users to retain the wide range of conventional PABX features while physically roaming across a business site — factory, office complex, campus, and so on — or even across a multisite private corporate network. Second, it offers



the potential for deploying full PABX functionality but without much of the expense, delay, and inconvenience of wiring up new premises. Opportunities for such new applications exist in situations in which temporary deployment of wired PABX functionality previously might not have been justified. Many of the associated problems arising from office relocation — rewiring, staff being inaccessible, and so forth — are avoided.

In addition to cordless access points, base stations, or cordless concentrators, a WPABX must be enhanced with mobility management intelligence that enables it to locate users and route incoming calls to the appropriate cordless base station/concentrator, thereby facilitating both incoming and outgoing calls for the user. Authentication/identification and billing/accounting functions are also required. ISDN as well as the voice capabilities supported by the PABX can also be supported by WPABX systems.

As a user arrives at a WPABX-provided site and wishes to operate his cordless telephone he first needs to register his presence on the system. This is done by switching on his handset, which causes the telephone to access the system and communicate its identity. Thereafter, the WPABX periodically polls or tracks its location — the radio coverage microcell in which it is located — to route incoming calls. DECT supports a powerful paging capability within its protocols, capable of accessing up to 6000 subscribers without needing to know in which cell they are currently located, thus reducing its location registration requirements. The provision of PABX-localized intelligence and intersite signaling to allow multisite roaming effectively introduces an almost IN type of capability into private networks, providing in effect a closed user group or private PCN. With increasing regulatory liberalization — for example, corporate private networks using spare capacity to carry third-party traffic — new commercial opportunities could emerge from such technological capabilities.

The need for in-call handover between cordless base stations in the business environment is not a universally agreed requirement. Some see in-call handover as being essential, but others maintain that for a slow moving pedestrian, or even a static office environment, such a facility is an unnecessary luxury. Such views probably reflect different types of users and different market sectors and, as such, it is a feature that manufacturers can offer in response to market demand. In-call handover within a radio cell and between cells is possible with both the CT2 and DECT standards. It has been demonstrated on current CT2-based products and will be standard with DECT.

WPABX implementation approaches adopted by different manufacturers have been described

[6] *Strictly, CT2Plus, an enhanced version of the CAI standard.*

in several references. Early CT3 systems developed by Ericsson [1] have been deployed and it is anticipated that their DECT systems will build upon this architecture [10]. The first systems being sold to a European standard are the CT2-based systems developed by GPT and Northern Telecom, which were demonstrated at Telecom 91 in Geneva and launched during 1992 (Fig. 5). The GPT products offer a cordless capability enhancement to their installed base of PABX customers, as well as to any other PABX with standard DPNSS signalling [9]. Such an enhancement capability is clearly important, because users with existing PABX facilities would prefer, if possible, to enhance existing equipment rather than have to bear the costs of early PABX replacement in order to secure the benefits of cordless access.

Beyond product development, both installation and maintenance support will be key for success in the WPABX market. Corporate telecommunications managers and PABX users generally have minimal awareness of the issues associated with radio propagation and coverage. They simply want 100 percent reliable, high-speech-quality telephone calls. For this reason, manufacturers are focusing on the development and provision of deployment and diagnostic guidelines and tools to facilitate the easy yet reliable installation of these three-dimensional microcellular systems.

Radio Drop

Since the initial conception of the "three-markets" model for cordless phones in the 1980s, technical, regulatory, and political developments have served to encourage a fourth potential market: wireless local loops or radio drops.

Traditionally, telecommunication services have been provided by wire from an exchange to the user's premises. The rapid advances in cellular radio, with the improved quality and reliability offered by the new digital standards, offer for the first time a cost-effective alternative to fixed wire interconnect. Falling equipment costs are becoming comparable with the costs of physically deploying and maintaining wire connections between the local drop point and user premises. However, this is not the only factor, because in many situations the wired connections already exist as a "sunk cost."

Another key factor encouraging radio drop has been the increasing liberalization of telecommunications monopolies in Europe, an EC policy associated with the development of the Single Market. This has resulted or is expected to result in changes to the regulatory framework to allow an increasing number of such applications.

The political changes in Eastern Europe have also given rise to a rapid proliferation of cellular systems for fixed and mobile telecommunications systems, given the poor state of the basic telecommunications infrastructure in many of these countries. In eastern Germany in particular, radio drop has been implemented rapidly since reunification. This demonstrates the potential of radio to supplant or augment traditionally wired applications.

The technical suitability of cordless technology for radio drop has been questioned by many, due to the low transmission powers (~ 10mW mean) and ranges (of order 50 to 500 meters or more depending on environment and antenna gain). Although it lacks the range and building penetration of higher power cellular or perhaps even DCS1800, the potential still exists to provide reasonable coverage using directional antennas and external rooftop stations wired to a normal telephone socket inside a house. Further, the costs of cordless technology are low compared with other options and the application is being vigorously promoted by some manufacturers [10].

Product Development and Availability

As previously noted, the first CT2 equipment available on the open market was built to proprietary non-CAI standards. Although these products failed to achieve large production volumes, the experience gained from these developments was valuable in the subsequent development of CAI products. The first CAI equipment to become generally available emerged from the two UK companies GPT and Orbitel, both of which supplied equipment for the early European Telepoint trial networks. GPT has also supplied production quantities of both base stations and handsets for the now commercially operational networks and was the first company to demonstrate its WPABX product offerings. Motorola is also emerging as a volume producer of CT2 Telepoint equipment and has announced an intention to cooperate with Northern Telecom to address the WPABX market. Several other companies have also indicated an intention to supply CT2 equipment, though some are still evaluating the development of the market before committing production capacity.

The summary of some of the actual and potential suppliers of CT2 and DECT equipment in Table 3 shows that several manufacturers are publicly supporting both DECT and CT2 developments.

Following the approval of the DECT standard by ETSI in 1992, product developments from a number of telecommunication manufacturers and chip suppliers are well advanced. Indeed, as with CT2, many of the manufacturers have been undertaking development work in parallel with the standards process. Although Ericsson has made much of claimed similarities between its proprietary CT3 (DCT900) system and DECT and is publicly targeting the DECT WPABX market with claims

Supplier	CT2 CAI	DECT
Alcatel		✓
Ascom		✓
Bosch		✓
Dassault	✓	
Ericsson	(via Orbitel)	✓
Fujitsu	✓	✓
GPT	✓	✓
Libera	✓	
Matra		✓
Mitel		✓
Motorola	✓	✓
Northern Telecom	✓	✓
Olivetti		✓
Orbitel	✓	✓
Panasonic	✓	
Philips		✓
Samsung	✓	
Shaye	✓	✓
Siemens	(via GPT)	✓
Sony	✓	✓

■ Table 3. *DECT and CT2 CAI equipment suppliers [7, 11].*

that it will be the first to market with such products, other manufacturers also clearly see this as a potentially important market. However, detailed timescale commitments for product availability from any manufacturer remain scarce at the time of this writing.

In addition to private DECT developments, various public validation systems based upon the emerging specification were constructed and used to provide technical input to ETSI during the past two years. These include the Italian Verification System and the UK DECT Testbed, which was constructed with the support of the UK government's LINK Personal Communications Programme. The latter system was constructed by a consortium of UK cordless manufacturers during 1990 and demonstrated to the ETSI RES 3 radio working group in spring 1991. Subsequent to this, the testbed equipments were used for a range of system performance trials in all likely DECT operating environments, both indoor and outdoor — such as shopping malls or along busy streets — with and without diversity. In addition, performance was measured using channel and interference simulators to gain performance data in a more controlled manner. Technical papers detailing trials and simulation results from this work were given to the standards committees. The construction of such validation systems has strengthened confidence in the DECT standard and helped to maintain the targeted timescales for standards development, as well as providing valuable experience for the participating manufacturers.

Category	Typical terminal bit rate (Mb/s)	System density (Mb/ha⁺/Floor) (⁺ha=10^4m^2)	Standardization responsibility
1	0.2	<1	RES 8, 2
2	2	3-10	RES 3 (DECT)
3	20	100-1000	RES 10 (HIPERLAN)

■ Table 4. *ETSI cordless LAN categorization.*

Cordless Data Applications

As noted earlier, cordless technology is not restricted to voice telephony, and indeed the cordless data market has become increasingly prominent in the past two years. As laptop computers have developed into first notebook and now palmtop computers, and as cordless and cellular technologies have dramatically advanced, the synergy of portable computing and radio communications has emerged as not only feasible but as a commercial imperative. In the U.S. the advent of the FCC Part 15 rules stimulated numerous spread spectrum approaches, while in Europe the need for standards prompted ETSI to establish an Ad Hoc group under RES to examine the matter during 1991. This led to the categorization of user capacity requirements (Table 4).

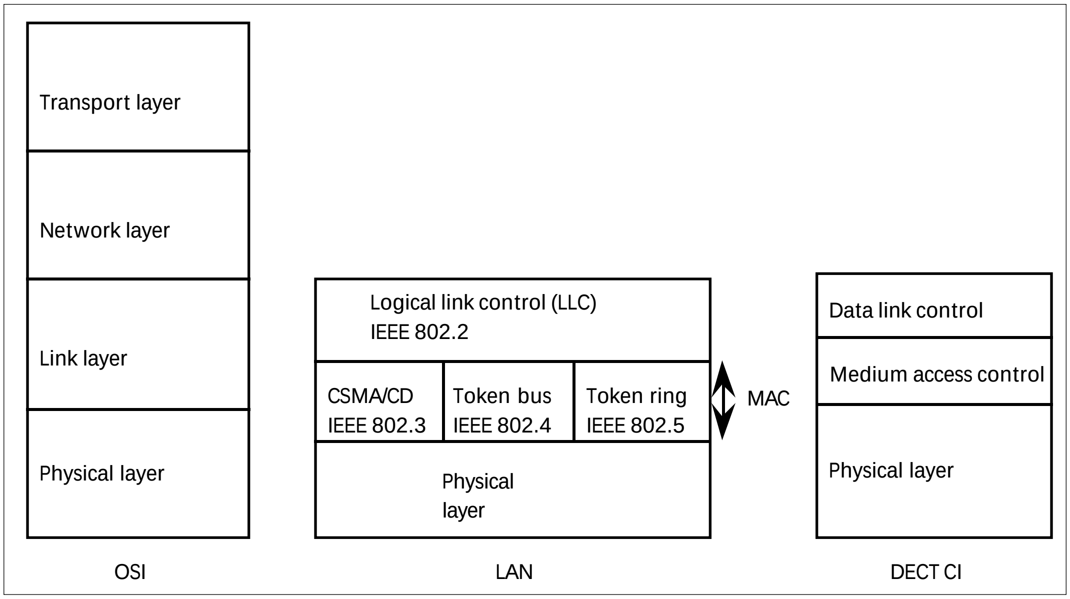
Because the DECT standard was specified for both voice and data applications, it was not surprising that ETSI confirmed a role for DECT to support medium-rate cordless LAN applications. The potential of spread spectrum systems has also been recognized and is now being examined within the ETSI RES 2 group. A new technical committee, ETSI RES 10, has been established to specify the High Performance European Radio LAN, or HIPERLAN (which is similar to IEEE 802.11). Outside Europe, extension of the CT2 standard to support data has also been implicit in the definition of CT2Plus for Canada. Thus, it would be inappropriate to review cordless technology without considering this application of the technology.

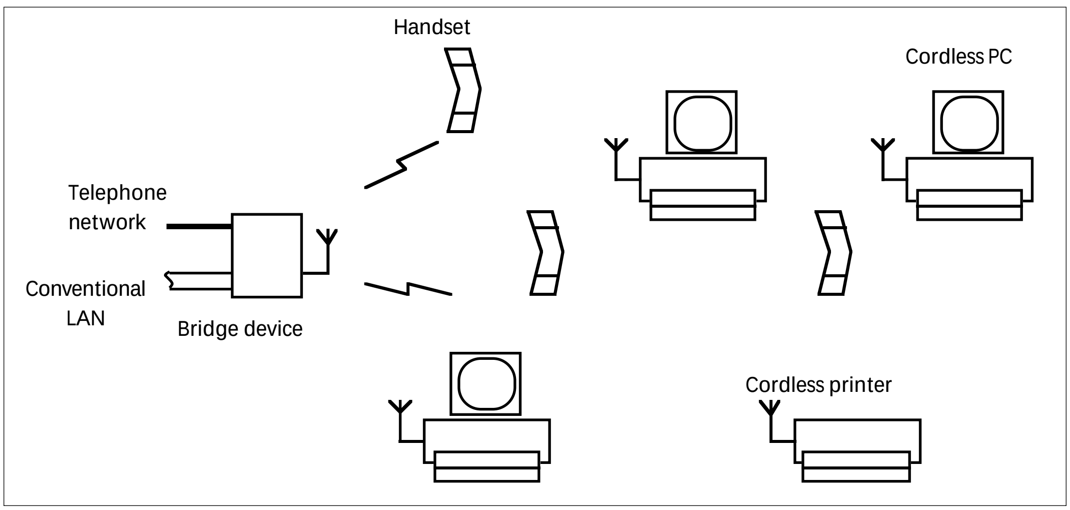
Cordless Data with DECT

The protocol stack for DECT is based upon the OSI layered model, as are LANs. The correspondence between layers is illustrated in Fig 6. The protocol systems used by LANs have been laid down in the various IEEE 802 standards; for example, Ethernet is based upon CSMA/CD, and is defined in IEEE 802.3.

An example cordless data configuration is shown in Figure 7. In such an arrangement, the bridge device must perform the interworking function between these IEEE 802 standards and DECT. If interworking is performed between the Logical Link Control (LLC) layer of the LAN protocol and the Data Link Control (DLC) layer of the DECT protocol, the system can be made to be independent of the particular LAN technology employed. The cordless cell can then be connected into an Ethernet, Token-Ring, or Token-Passing Bus. (It is assumed that the protocols across the LAN and across the DECT interface are fully terminated in each case. The prob-

In the LAN application, DECT uses multiple time slots and assymetric transmission to support higher instantaneous data rates.





lems of converting data rates, formats, and protocols at the wire-to-radio interface make any kind of single end-to-end protocol impractical).

The bridge device examines the addresses of data packets and routes them appropriately. In general, most of the traffic on the conventional LAN will not find its way over the DECT radio interface. Only data packets for the cordless stations will be transmitted within the cell. This means that the bit rates offered by DECT do not result in a punitively low data throughput. Ethernet is based upon a fundamental bit rate of 10 Mb/s. However, a site-wide LAN backbone may well service the needs of hundreds of users. By comparison, a DECT radio cell inherently constitutes a small area and hence needs to carry only a small proportion of the total traffic.

The majority of traffic will be carried using connection-oriented procedures from the DECT standard — a DECT call is set-up and released for every packet transferred. A restricted amount of all-station information is also transferred using connectionless procedures. For example, information relating to the structure of the network can be broadcast to all stations using connectionless procedures.

Cordless stations automatically register their presence over-the-air when they arrive in a new radio cell. This means that a PC could be moved from one office to another without having to go through complicated reconfiguration procedures. All cordless stations synchronize their receiver scans to that of the bridge. This allows the use of fast set-up procedures, reducing the overhead at the start of each packet to just two frames [12].

For normal telephony applications, DECT uses duplex pairs of timeslots to achieve reciprocal data throughputs of 32 kb/s, as indicated in Fig. 2. In the LAN application, much higher instantaneous, unidirectional data rates are needed. This can be achieved by the use of multiple timeslots and the use of both the uplink and downlink slots (as they would be used for telephony) for transmission in the same direction, i.e. assymetric transmission.

Because the DECT standard allows considerable freedom in the choice of parameters for implementation of data services such as cordless LAN, a range of different system configurations and implementation options may be envisaged. Analytical and simulation work on such systems has recently been reported in the literature, indicating user data rate performance up to a few hundred kilobytes per second [13]. Such simulations are particularly valuable in allowing the tradeoffs between user data rates and access latency to be quantified for different implementation approaches.

It is notable that the most publicized DECT product development to date has in fact not been for simple telephony applications but rather for data, as in Olivetti's cordless LAN [14]. A prototype of this product was demonstrated at the ITU Telecom exhibition in Geneva in October 1991; products were scheduled to be available this year.

Cordless Data with CT2

By virtue of being originally conceived as supporting digitally encoded voice services, CT2 is also capable of supporting data services. With the initial emphasis in Europe on CT2 usage for Telepoint, the task of enhancement of the standard for data has occurred largely in Canada, where data standards have been included in the CT2Plus specification. Four different types of circuit-mode data-bearer services are specified over the 32-kb/s B channel in the specification: full-duplex asynchronous data services, full-duplex transparent (including synchronous) data services, packet data, and Group 3 facsimile.

Asynchronous data services allow communication with wired computer facilities at asynchronous rates of 300, 1200, 2400, 4800, 9600, 14400 or 19200 b/s and employ a combination of automatic repeat request (ARQ) and forward error correction (FEC). Flow control is employed to moderate the user terminal or host computer data rate under conditions of radio path degradation.

Transparent data bearer services offer the user unrestricted access to the 32-kb/s B channel or to lower rate channels, with rates synchronous and user-selectable, thereby enabling the support of data services not otherwise explicitly supported by the specification. The transparent service provides FEC (except at 32 kb/s), but not ARQ.

The packet data service enables the use of X.25- or ISDN-based packet equipment. Further, a point-to-multipoint packet mode data bearer service can also be implemented, with the cordless base station acting as a hub of a star configuration for applications involving sporadic data or low average traffic per user. An enhanced reservation ALOHA scheme is used to arbitrate access in this latter case.

The Group 3 facsimile capability enables the operation of standard facsimile machines via cordless links over either a packet-switched connection or a public or private packet data network that supports facsimile packet assembly/ disassembly.

Integration of Voice and Data

At first sight, the achievable bit rate across the radio interface would appear to be a major limitation of using existing cordless standards for implementing LAN or other data functions. However, because this interface is used only for transmitting data for stations within a single radio cell, this is not as serious a problem as it might first seem. Existing cordless standards hold considerable promise for applications such as electronic mail, the transfer of small to medium size files, and terminal concentrators. Nevertheless, there are applications for which such systems would clearly be unsuitable, such as for connecting high-speed graphics servers or for providing site-wide LAN backbones.

Because a great deal of effort has been dedicated in Europe to develop cordless telephone equipment, the radio designs required for cordless data and LAN equipment are already available. Further, the technology allows integration of PABXs and LAN systems, with the bridge device and cordless base station being integrated into the same physical equipment.

Although a strong latent demand for cordless data applications apparently exists, the pace of integration of such services with the wireless PABX remains uncertain, as the market is still at an early stage. The likely development of the integrated cordless voice and data market is clearly related to demand for wired integrated services. While to date this latter market has not met early expectations, demand will emerge in due course — the lack of widespread availability of network and equipment capabilities and of value added services have been interrelated factors, all of which are now progressing across Europe. Various initiatives, both national and pan-European, are expected to stimulate these markets over the coming decade.

Beyond Today's Cordless Access: UMTS and FPLMTS

The migration of microcellular cordless techniques for wider area systems has already begun. The original PCN initiative in the UK and the subsequent initiatives in Europe and North America have all served to hasten technical progress in personal communications, not only at the radio level but also at both network and service levels.

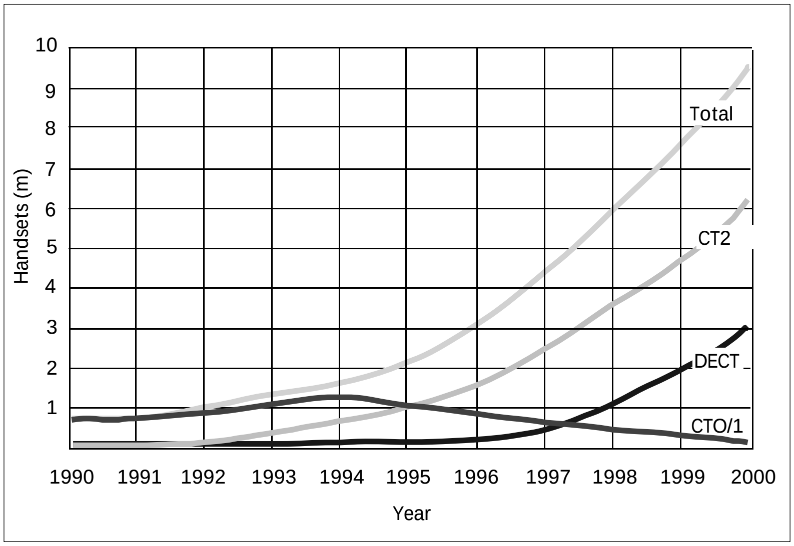
Looking beyond today's second-generation digital cordless and cellular systems, extensive research is underway to define the elements and architecture of third-generation systems — ETSI's Universal Mobile Telecommunications System (UMTS), and the Future Public Land Mobile Telecommunications Systems (FPLMTS), now under development by CCIR, with assistance from CCITT. The degree of standards commonality between these initiatives remains to be seen — while political and commercial sensitivities could militate for or against common standards, it is encouraging to see the high level of common participation across the relevant standards bodies and the statements of intent to seek collaboration and cooperation.

Universal Personal Telecommunications, UPT, which is being specified by CCITT and ETSI, will be an important precursor to UMTS/FPLMTS. It has the potential to implement personal numbering (as opposed to location-dependant numbering) in advance of third generation systems. This is likely to be an important aspect of market education. The availability of UPT will further the development of a true consumer marketplace for the advanced personal telecommunications products over the next decade.

Several new UMTS research projects began at the start of 1992 with the support of the European Commission under the RACE 2 program. The projects address network, service, and radio

The original PCN initiative in the UK and the subsequent initiatives in Europe and North America have all served to hasten technical progress in personal communications.

[7]Further details on third-generation systems and the UMTS work of the RACE program are given in the article by Stanley Chia of British Telecom elsewhere in this issue.



access issues. With support from the major manufacturers, operators, and administrations across Europe, these projects will feed results into both the ETSI and CCIR work.[7]

Cordless and PCN/PCS

How will be the role of cordless technology in PCS develop in the coming years? In answering this question it is important to bear in mind that personal communications services are supported by networks — PCN, cellular, fixed, and so on. Cordless-access technology offers low-cost portable handsets, data terminals, and base stations that can be configured and managed to access services via such networks. As the demand for mobility continues to increase, cordless-access technology will have a role in many different scenarios and applications, limited perhaps more by regulatory factors than technical ones.

In personal communications services, low terminal and infrastructure costs are a factor in providing low-priced services and hence volume penetration. In this respect, cordless access systems appear inherently cheaper than the initial European PCN offering, DCS1800, and lack the complexities of equalization and frequency planning — even considering relative-volume economies and learning-curve factors.

The reduced area coverage capability of Telepoint public access clearly limits the level of service, but to one that is quite adequate for many consumers. Indeed, in limited high user density areas, full area Telepoint coverage using multiple cheap base stations has been proven practicable. The commercial moves to incorporate, at the minimum, paging and subsequently two-way calling features are pushing the Telepoint capabilities increasingly upmarket, although the technology costs remain acceptably low.

In practice however, Telepoint will not compete head on with DCS1800 or cellular, because the infrastructure costs for comparative wide area coverage would be prohibitive. Although PCN will provide a higher service level for professional users who are prepared to pay for such services, Telepoint appears to be ready to provide the first truly consumer mobile communications offering. In this respect, it will play a key role in many countries in familiarizing the consumer marketplace with the practical concepts of telephony on the move, and indeed stimulating the market for other personal communications services.

In business environments it is possible in principle to integrate or at least interface the mobility management of private and public systems, and in a similar way to make use of existing links between corporate and cellular networks. How such a potential integration/interfacing might develop remains to be seen, and may differ between countries. The potential for integrating in-building WPABX services with public access Telepoint or even PCN, however, could provide interesting new commercial opportunities.

Conclusion

European consumers have yet to appreciate the potential of personal communications. Still, in 1992, mobile telephony is for the vast majority of Europeans a business tool rather than a consumer product. Although the market is indeed moving toward a mass-market, this transition is still at an early stage. Early market experience reinforces the importance of education — for example, people need to get used to the idea of communicating while on the move, before the desirability of a single pocketphone that can be used in all locations becomes a significant consideration. Telepoint will play a part in this process.

While the elegant concept of three symbiotic application markets — allowing the use of a single cordless handset in domestic, business, and public environments — is intuitively attractive, it may be equally illusory and in reality a long-term scenario. Initial Telepoint market success in Asia could be interpreted as casting some doubt on the model; perhaps it should be treated as a guide, not a rule.

Market forecasts for cordless phones in European markets continue to be bullish, as shown in Fig. 8. Such predictions indicate market success for both the CT2 and DECT standards, and this may be why most manufacturers continue to support both standards. It is quite possible that as the market matures and demand for integrated voice and high rate ISDN services develops, the balance between DECT and CT2 will change. National, geographic, and cultural preferences will also affect market acceptance. Many people perceive DECT and CT2 as addressing different market sectors, goals, and timeframes, but at present it appears that both standards have the potential to succeed. Given that the GSM digital cellular standard is now being adopted in so many countries worldwide, one may anticipate similar success for these established European cordless technologies.

The emerging personal communications industry in Europe has learned some hard lessons as it has pioneered PCN and Telepoint concepts, technology, and services in recent years. It is now set, however, to reap some of the rewards. Standards are firm, prototype networks have been tested, commercial systems are being installed and operated worldwide, and digital WPABX products are now available. User and operator experience with these systems over the next few years, during the transition from being a technology-led niche business market to a market-led consumer one, will be a key factor in shaping the development of personal communications services for the year 2000 and beyond.

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Biography

WALTER H. W. TUTTLEBEE [SM] graduated from the University of Southampton in the UK with a B.Sc. degree with honors in electronics in 1974 and a Ph.D. in 1978. Following postdoctoral research, he

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