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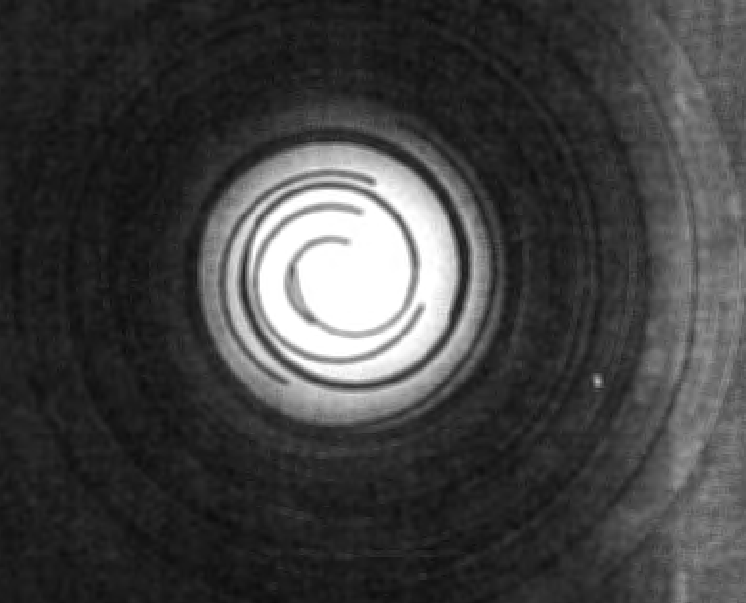

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Chapter 11

Survey and Analysis of Second-Generation European Mobile Communications Systems

11.1 CELLULAR MOBILE RADIO SYSTEMS

11.1.1 Analog Cellular Mobile Telephone Systems

11.1.1.1 Cellular Infrastructure Development

Eight different cellular mobile-telephone systems are currently providing services in all EC and EFTA countries except Greece. The first European country to introduce a cellular telephone system was Sweden in August 1981, followed by Norway (November 1981), Denmark (January 1982), Finland (March 1982), Spain (November 1982), Austria (November 1984), United Kingdom (January 1985), Netherlands (January 1985), Luxembourg (August 1985), Germany, Italy (September 1985), France (November 1985), Ireland (December 1985), Iceland (July 1986), Belgium (April 1987), Switzerland (September 1987), and Portugal (January 1989). Table 11.1 depicts the numerous systems presently operating in Europe, along with their respective date of launch.

The deployment of a multitude of incompatible systems precluded the provision of Pan-European roaming from the outset onwards. Terminal equipment designed for one system (e.g., NMT-450, NMT-900, C-450, etc.) cannot be used in a market served by a different system. Transborder roaming agreements are therefore only feasible between countries using the same cellular standard. At present, two intra-European roaming areas exist. The four Scandinavian countries—Denmark, Finland, Norway and Sweden—have full roaming agreement for their NMT-450 and NMT-900 systems, while the three countries in the middle of Europe—Belgium, Luxembourg, and Netherlands—offer roaming services on their compatible NMT-450 systems [1]. A potential third roaming agreement between Austria, Italy, and Spain (TACS-900) is under discussion. However, no roaming is possible between the systems installed in

Table 11.1
Mobile Communications Systems in EC, EFTA, and Selected Nordic Countries, as of April 1, 1991

Country	*EC/EFTA*	*NMT 450*	*NMT 900*	*TACS 900*	*Other Systems*	*Launch*
Austria	EFTA	XXX				Nov. 84
				XXX		Jul. 90
Belgium	EC	XXX				Apr. 87
Denmark	EC	XXX				Jan. 82
			XXX			Dec. 86
Finland	EFTA	XXX				Mar. 82
			XXX			Dec. 86
France	EC				RC2000	Nov. 85
					NMT-F	Apr. 89
Germany	EC				C-450	Sep. 85
Iceland	EFTA	XXX				Jul. 86
Ireland	EC			XXX	Dec. 85	
Italy	EC				RTMS	Sep. 85
				XXX		Apr. 90
Luxembourg	EC	XXX				Jun. 85
Netherlands	EC	XXX				Jan. 85
			XXX			Jan. 89
Norway	EFTA	XXX				Nov. 81
			XXX			Dec. 86
Portugal	EC				C-450	Jan. 89
Spain	EC	XXX				Jun. 82
				XXX		Apr. 90
Sweden	(CEPT)	XXX				Oct. 81
					Comvik	Aug. 81
			XXX			Dec. 86
Switzerland	EFTA		XXX			Sep. 87
U.K.	EC			XXX		Jan. 85

Source: "Mobile Communications guide to European subscribers to mobile systems," FinTech Mobile Communications, 5; Modified and supplemented by Author.

the four largest economies in Europe: Germany, France, Italy, and the United Kingdom.

Based on information presented in Table 11.1, European mobile cellular-telephone systems may be divided into essentially two groups. The first category includes systems that are implemented in three or more countries, and which are used by at least 10% of all European subscribers to mobile telephone services. The second category is made up of systems generally used in only one country and having a respective subscriber base of less than 10% (See Table 11.2). It is interesting to note that three of the four major European economies, namely Germany, France, and Italy commenced on launching their own noncompatible cellular systems between September and November 1985—almost four years after the NMT-450 was initially introduced in Sweden and subsequently installed in Norway, Denmark, Finland, Spain, and Austria. The proliferation of incompatible cellular-telephone infrastructures in Europe provides a good example of how insufficient standardization and protective national procurement policies led to a duplication of R&D efforts, as well as the nonrealization of economies of scale.

Between its introduction in October 1981 and 1989, the NMT-450 system operated in more countries and served more subscribers than any other competing system. During 1989, the number of subscribers using the TACS (total access communications system)—although then only deployed in the United Kingdom and Ireland—surpassed the NMT-450 system's subscriber base (see Fig. 11.1).

At the same time, the NMT-900 system was capable of progressively closing the "subscriber-gap" to the NMT 450 system, and eventually surpassed the NMT-450 system technology market share during the first half of 1991. Notwithstanding, the TACS system remained the fastest growing cellular system, after Austria, Spain, and Italy opted to install TACS technology. During 1990, the TACS subscriber-base grew by 41%, compared to NMT-900 (25.5%); NMT-450 (11.1%); C-450 (10.1%); RC2000 (5.4%); and NMT-F, RTMS, and Comvik, with a combined 6.9%. In March 1991, the three major systems (i.e., TACS 900, NMT-450, and NMT 900) provided service to 80.1% of all cellular customers in EC or EFTA countries.

11.1.1.2 Regulatory Aspects

Based on the description of the European telecommunications policy, prior to the partial implementation of the Green Paper recommendations [2], it is clear that cellular-telephone services in most European (and EFTA) countries were exclusively provided by monopolistically operating PTTs. Within the twelve EC Member States, however, there are exceptions: the United Kingdom and France.

From the early 1980s onward, the United Kingdom's telecommunications market has consistently been the most liberalized one among all its EC neighbors. One year after awarding Mercury a license to provide fixed network services, the U.K.

Table 11.2
Overview of European Cellular Telephone Systems as of April 1, 1991

Systems Type	*Freq. Band (MHz)*	*Occup. Bandwth (MHz)*	*Channel Spacing (kHz)*	*Countries*	*Subscriber*	*-%*	*Oper. Since*
TACS-900	900	15	25	U.K., Ireland, Italy, Austria, Spain	1,494,790	40.1	1/85
NMT-450	450	4.5	25	Austria, Belgium, Denmark, Finland, Iceland, Spain, Netherlands, Sweden, Norway, Luxembourg	777,860	20.9	10/81
NMT-900	900	25	12.5	Netherlands, Norway, Denmark, Finland, Sweden, Switzerland,	713,420	19,1	12/86
C450	450	4.5	20	Germany, Portugal	319,040	8.6	9/85
RC2000	200	28	12.5	France	245,000	6.6	11/85
RTMS	150	N/A	N/A	Italy	93,400	2.5	9/85
NMT-F	450	6	N/A	France	65,000	1.7	3/89
Comvik	N/A	N/A	N/A	Sweden	17,900	0.5	8/81
Total					3,726,410	100	

Data: Balston, ''PAN-European cellular radio,'' 7; ''European Cellular System Summary,'' 16.

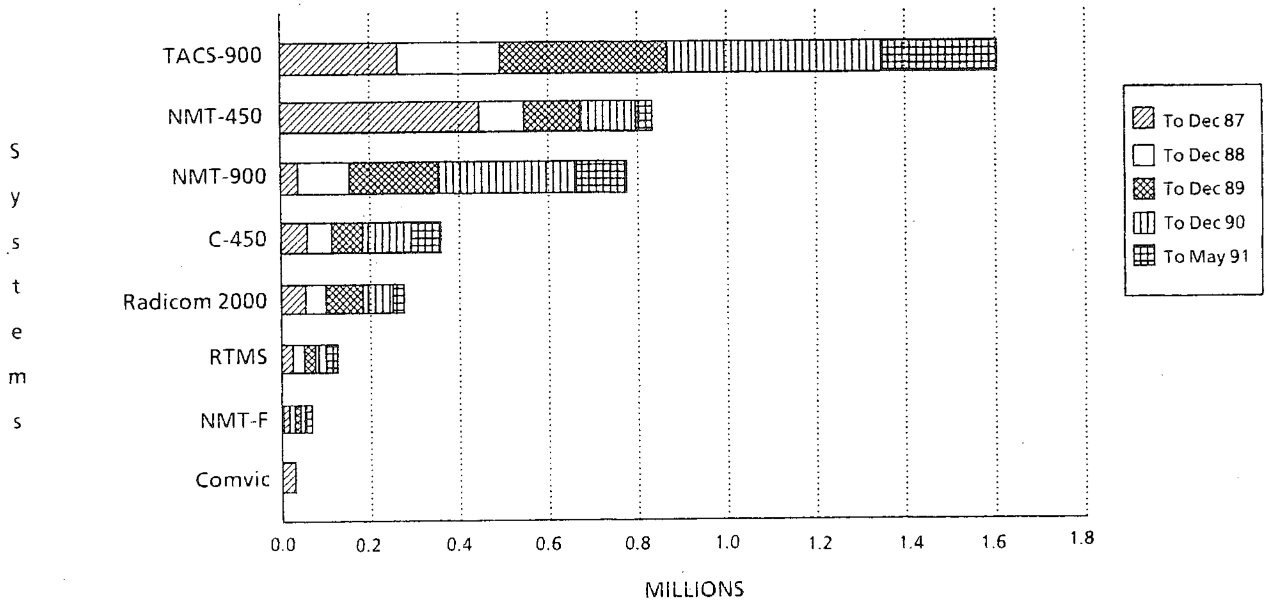

Figure 11.1 The diffusion of European cellular telephone systems between 1987 and March 1991. (Source: "European Cellular System Summary)

Government in 1983 extended its duopoly policy to provide mobile telephony, and consequently licensed two cellular network operators—Cellnet, a joint venture between British Telecom and Securicor [3], and Racal-Vodafone [4]. The licenses for two TACS systems, each using 15 MHz, were issued on condition that both systems were operable by April 1985, and covered at least 90% of the population by 1990 [5]. In order to elevate the competitive pressure between both network operators, the U.K. Government adopted the so-called two-tier approach to service provision, meaning that the actual service provision function and the marketing and distribution functions are separated. Cellnet and Racal-Vodafone operate the network (first tier) and also appoint airtime distributors or resellers (second tier), which then sell airtime and equipment to end users [6]. A detailed analysis of the merits of such a regulated cellular market will be given in the following section.

As noted above, France is the second EC Member State that licensed a competitive (analog) cellular network operator. The first quasi-cellular telephone network [7] introduced in France, in November 1985, is the Radiocom 2000 system operated by France Telecom. Amidst an intensifying discussion regarding the deregulation of services, the Ministry of Posts, Telecommunications and Space (PT&E) [8] decided in July 1987 to license a second, independent network-operator [9]. The decision was partly motivated by the trailing performance of France with regard to the penetration-rate of mobile communications systems (e.g., cellular) as compared to other European countries [10]. The license was awarded to Societe Francais du Radiotelephone (SFR), a consortium whose largest shareholder is Compagnie Generale des Eaux [11]. The system commenced operation in March 1989 with an initial frequency spectrum allocation of 2 MHz—later increased to 6 MHz—and a total (initially) projected capacity of 120,000 subscribers [12]. In addition, both cellular operators are presently in the process of creating a two-tier service structure according to the U.K. model. In fact, SFR intends to commence reselling airtime for its analog system from early 1992 on. In contrast, France Telecom will not begin selling through service providers prior to the launch of its second cellular mobile-telephone system [13]. Table 11.3 gives an overview of entities operating analog cellular telephone systems [14] within the twelve EC countries.

11.1.1.3 Market Aspects

The development of the number of subscribers in 11 EC countries and 5 EFTA countries illustrates the irregularity with which the technology diffused in various European countries.

In 1985, for example, more than 75% of all users of cellular services in the above-stated nations were accounted for by the four Nordic countries forming one intra-European roaming area: Finland (11%), Denmark (17%), Norway (23%) and Sweden (24%). In contrast, the four major EC countries introduced their non-

Table 11.3
Operators of Analog Cellular Systems Within the European Communities

Country	*Operator*	*No. Sys.*	*Country*	*Operator*	*No. Sys.*
U.K.	Cellnet	1	France	France Telec.	1
	Racal Vodafone	1	SFR		1
Germany	DBP Telekom	1	Belgium	RTT	1
Denmark	Telec. Denmark	2	Italy	SIP	2
Ireland	Telec. Eireann	1	Greece	None	0
Luxembourg [15]	via Netherlands	1	Netherlands	PTT Telec. BV	2
Portugal [16]	Movatel	1	Spain	Telefonica	2

compatible cellular systems significantly later. Hence, by 1985 these countries had only 17.7% of the total subscriber base of all seventeen countries: United Kingdom (16.3%), France (0.04%), Germany (0.5%), and Italy (0.9%). During the following five years this situation almost reversed itself. In 1990, the subscriber base of the four Scandinavian countries decreased to 31% compared to the total number of users in all seventeen European nations, while the four major EC countries— United Kingdom (33%), Germany (8%), Italy (7.7), and France (8.8%)—reached a combined 57% . As deducible from Table 11.4, the United Kingdom recorded a dramatic increase in subscribers between 1985 and 1990, and clearly dominates the European cellular market with more than 1.1 million (33%) cellular users.

The above-stated absolute subscriber numbers do not explicitly take the market size into consideration. In order to be able to evaluate the relative diffusion of cellular telephone service in these countries, the penetration rate (i.e., the number of users per 1000) must be compared. Table 11.5 depicts the penetration rate for the 17 European countries [17].

The data compiled in Table 11.5 illustrates a significant disparity between the ranking in market size and the ranking in penetration levels. Indeed, the four Scandinavian countries enjoy the highest penetration levels in Europe. In contrast, the more populated countries, such as Germany, Italy, France, and Spain, have penetration levels in the order of one-tenth of that of Sweden and Norway. Crucial factors are, inter alia, terminal prices, service charges, and the number of years cellular systems are in operation (see Table 11.6) [18]. The high penetration rate in Sweden and Norway, for example, coincides with the fact that their respective cellular systems have been operational since 1981, while the cellular networks in France, Germany, Italy, and the United Kingdom were not launched prior to 1985. Substantial discrepancies are also noticeable with regard to the terminal prices and service charges in the European countries.

Table 11.4
European Cellular Telephone Subscribers 1984-1990

Country	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*
Austria	9,762	17,454	26,223	36,904	50,721	72,407	114,307
Finland	32,309	49,600	17,598	104,551	157,969	225,983	287,097
Iceland	——	2,106	5,008	6,519	7,893	10,010	12,889
Norway	63,186	87,061	120,029	152,103	173,237	203,312	234,423
Switzerland	——	——	5,470	30,770	73,000	126,047	174,557
Sweden	65,000	110,000	150,000	220,000	350,147	482,903	589,182
Belgium	——	——	5,700	19,160	31,000	47,170	50,478
Denmark	46,098	57,604	78,215	101,215	123,870	149,186	176,933
France	114	9,482	39,254	98,338	179,500	283,506	373,395
Germany	1,103	17,973	48,747	99,865	165,000	273,860	532,251
Ireland	135	1,000	2,800	5,300	10,500	22,097	31,696
Italy	2,320	4,095	13,240	31,860	66,000	265,902	567,498
Luxembourg	60	160	260	360	450	608	873
Netherlands	4,800	12,600	22,000	32,000	50,000	81,510	116,900
Portugal	——	——	——	——	2,900	6,386	12,570
Spain	772	1,693	4,225	11,629	30,000	54,958	108,451
U.K.	44,000	122,000	260,000	507,000	860,000	1,139,500	1,230,100
Total	269,659	492,928	852,569	1,457,734	2,338,516	3,449,704	4,615,600
Annual Growth %	100%	83%	72%	71%	60%	47%	34%

Source: McCartney, "How competition is developing in global markets," Chapter 4. Supplemented by: FinTech Mobile Communications Issue 73 (February 1991). Market Data for 1991: MZA, Wiltshire, England.

In fact, equipment prices within these countries vary by more than 150%, reaching from $1,140 in Sweden to $2,780 in Luxembourg [19]. Even more extreme are the differences with regard to the monthly service charges, which are spanning a range from $68 in Iceland to $361 in France. To determine whether—and if so, to what extent—equipment and service prices influence the penetration rate, a linear regression analysis was performed. The result indicates that the two independent variables, equipment prices and service charges, are poor determinants of the actual penetration rate. More particularly, the linear regression had a large standard error of 16.82, and an R-square of only 0.33. Based on these values, it can be concluded that equipment prices and service charges are insufficient to prognosticate the penetration rate within a country. In a second step, two additional, independent variables were included: the number of years since a cellular system was first launched in a country,

Table 11.5
Cellular Market Penetration in the EC, EFTA Countries, and Sweden in 1990

Country	*Population (millions)*	*Penetration per 1,000*	*Country*	*Population (millions)*	*Penetration per 1,000*
Sweden	8.4 (9)	70.0 (1)	Ireland	3.5 (15)	9.0 (10)
Finland	4.8 (13)	59.8 (2)	Germany	61.2 (1)	8.7 (11)
Norway	4.2 (14)	55.7 (3)	Netherlands	14.7 (6)	7.9 (12)
Iceland	.24 (17)	53.7 (4)	France	55.6 (4)	6.7 (13)
Denmark	5.1 (12)	34.7 (5)	Belgium	9.9 (8)	5.1 (14)
Switzerland	6.6 (11)	26.4 (6)	Spain	38.8 (5)	2.8 (15)
U.K.	56.9 (3)	21.6 (7)	Luxembourg	0.4 (16)	2.1 (16)
Austria	7.6 (10)	15.0 (8)	Portugal	10.3 (7)	1.2 (17)
Italy	57.3 (2)	9.9 (9)			

Note: Germany does not include the population of the former East Germany. Data based on Table 10.1 and Table 11.4.

and the gross-domestic-product per capita. The result of the second regression analysis showed a lower standard error (10.5) and a significantly higher R-square (0.77). Hence, 77% of the variations of the penetration rate can be explained by the four independent variables.

Of interest also is the question of to what extent terminal prices and services charges are related. Based on a regression analysis, it can be concluded that there is no correlation between these two factor, as reflected by an R^2 of 0.07. Further analysis of data in Tables 11.4 and 11.5 clearly indicates the cost-penalties associated with fragmented, national markets. While terminal prices in the five Nordic countries (Sweden, Norway, Finland, Iceland, Denmark) average $1,380, equipment in the three large EC markets with incompatible systems (i.e., France, Germany, and Italy) average $1,976. The extremely low terminal price of $20 in the United Kingdom is a reflection of the intense competition between the two competing airtime providers and the two-tier structure. Indeed, service providers began to heavily subsidize mobile telephones [20]. As noted by a recently performed study, equipment prices—and not airtime prices—are used to create markets [21]. Hence, while equipment prices have declined rapidly, service charges remained at high levels.

In summary, it can be concluded that there is presently no homogeneous European market for cellular telephony. In fact, considerable differences are evident in virtually all areas associated with the provision of cellular services (i.e., penetration, terminal prices, airtime).

Table 11.6
Lowest Available Cellular Equipment Prices and Service Charges in EC, EFTA Countries, and Sweden, as of September 1, 1990

Country	*Terminal Local (Currency)*	*Terminal (US$)*	*Monthly Service (US$)*	*Country*	*Terminal Local (Currency)*	*Terminal (US$)*	*Monthly Service (US$)*
Spain	Pta 300,000	2,780	141	Finland	Fmk 7,000	1,770	197
							125
Portugal	Esc 400,000	2,700	124	Netherlands	Fl 3,230	1,720	162
							159
Germany	DM 4,250	2,530	278	Italy	£ 1,900,000	1,590	149
France	Fr 12,500	2,190	361	Denmark	Kr 9,500	1,470	100
			322				
Luxembourg	Fr 75,000	2,150	229	Iceland	Kr 80,000	1,330	68
Belgium	Fr 75,000	2,140	127	Sweden	Kr 7,000	1,140	134
							123
Austria	Sch 25,000	2,120	132	Ireland	£ 700	1,110	147
Switzerland	SFr 3,000	2,010	88	U.K.	£ 10	20[19]	155

Note: Monthly service charges are based on five two-minute calls per day during peak time Monday to Friday for one month.

Source: McCartney, "How Competition Is Developing in Global Markets," chap. 4.

11.1.2 GSM—Digital Cellular Mobile Telephone System

11.1.2.1 The Development of a European Cellular System

In 1981, France and Germany initiated a joint-study program for a second-generation digital cellular system. To prevent a technological fragmentation, as was the case with the first generation of cellular systems, the European Conference of Postal and Telecommunications Administrations (CEPT) established in 1982 a special working group—the groupe special mobile (GSM) [22]. By 1986, the working group started testing various technological concepts in Paris and finally decided—after an intensive debate—that the group named standard (GSM) for the first European digital cellular system should be based on TDMA [23].

In order to cement a Pan-European solution, the Council adopted 1987 Recommendation 87/371/EEC [24] for the coordinated introduction of public Pan-European digital-mobile communications, and Directive 87/372/EEC [25] on the frequency bands to be made available for the cellular system. According to the Directive, the

Member States will have to assign an increasing part, and eventually all, of the 890-915 MHz and 935-960 MHz spectrum to the GSM network(s). The Recommendation specified that the commercial service should begin in 1991, following preoperative trials. By 1993, the minimum coverage area of the GSM system in all Member Countries should include capitals and airports, and should then be extended to cover the transport routes between capitals during the following two years. In reaction to the Council Recommendation 87/371/EEC, a Memorandum of Understanding (MoU) had been ratified initially by 17 European telecommunications organizations, among them all EC PTTs. The signatories of the MoU are committed to implementing the 900 MHz digital cellular system with international roaming capabilities, in adherence to the Council Recommendation and Directive. In contrast to the anticipated implementation of digital cellular mobile telephone systems in the United States [26], European GSM networks will operate entirely independent from existing analog systems. Specifically, GSM will be exclusively allocated 2×25 MHz in the 900 MHz frequency band, and terminal equipment is designed to work only within the GSM network. While this approach is beneficial in that no dual-mode MS is required, it is obvious that a user is confined to a smaller coverage area in the initial phase of network construction and expansion.

11.1.2.2 Technological Aspects

11.1.2.2.1 The GSM Standard

The GSM public land-mobile cellular system is comprised of two parts—a base station subsystem, and a network subsystem. The GSM standard itself is an open nonproprietary-standard, which means that not just the air interface [27] is specified but all interconnections between the base station and network subsystems. It is, therefore, possible that cellular system components are supplied by different vendors. Also, the CEC strongly encouraged this development, since it allows smaller companies to participate in the market with certain niche products [28]. With regard to the ISO seven-layer model, GSM is defining layers 1, 2, and 3 (i.e., physical, data link, and network layer). As mentioned in Section 10.2.5, the work for the GSM standard was transferred in 1989 from CEPT to ETSI. The GSM standard itself includes 164 Recommendations, of which 121 have been stabilized during the so-called Phase I [29]. In fact, these Recommendations specify the various interfaces between the key elements of the system (i.e., air interface, fixed network, base stations, and mobile stations, as well as all switching and networking aspects) [30]. The remaining 43 Recommendations essentially focus on the definition of supplementary services and half-rate codecs, and are going to be completed in Phase II [31].

On the outset of the GSM standardization process, substantial efforts were concentrated toward evaluating and selecting the most appropriate radio technology for the link between BS and MS. Three alternatives were available: FDMA, TDMA, CDMA. In the end, a digital transmission method, TDMA, was chosen. One of the major reasons for favoring a digital standard was the fact that digital systems greatly facilitate the incorporation of improved single elements (e.g., voice coders) without needing to redesign the entire system [32]. The various technical aspects that have to be considered for the design of spectrally efficient digital communication systems were delineated in Section 5.4. One of the most important decisions lies in the trade-off between speech quality and bit-rate. The initial (Phase I) speech codec used for the GSM system is 13 kbps RELP-LTP (residually excited linear-predictive coder with long-term predictor) [33]. Gaussian mean shift key modulation (GMSK) was chosen for the modulation of the bit stream. The channel spacing of the GSM system is 200 kHz and provides a data transmission rate of 270,833 kbps. Given the assumed nominal user data rate of 16 kbps, the GSM system offers 8 channels per 200 kHz band. As briefly mentioned, Phase II of the GSM specification process will inter alia standardize a half-rate codec, which will provide toll-quality with a 8 kbps codec. This will effectively double the capacity of GSM, since 16 instead of 8 duplex channels can then be accommodated per 200 kHz band.

In light of the radio environment of the GSM system—frequency (900 MHz), cell size (up to 35 km), and speed (up to 250 km/h)—it is clear that multipath propagation represents a potentially severe problem [34]. Instead of opting for bit rates that are sufficient to compensate for the multipath delays, the GSM system employs an equalization technique. Although equalization allows for shorter bit rates, and is therefore a more spectrum-efficient solution, it is highly processing intensive, requiring VLSI chips with 50,000 and more gates [35]. The overall complexity of the GSM system is reflected in the product development of leading manufacturers, which will initially require seven to ten VLSI chips totaling 600,000 transistors, as well as microprocessors, memory chips, and at least 125 kbytes of software [36]. To achieve size and cost advantages, it will be necessary to combine all functions in one single chip [37].

11.1.2.2.2 The GSM System

The main switching elements of the GSM system are identical to the ones outlined in Section 4.2.1.3. As depicted in Figure 11.2, the base station subsystem includes base transceiver stations (BTS) and base station controller (BSC). The base station subsystem is principally responsible for establishing, synchronizing, and maintaining the radio link between BS and MS.

The network subsystem is composed of network databases such as the visitor location register (VLR), the home location register (HLR), the authentication centers (AUC), the equipment identity register (EIR), and—most important—the mobile switching center (MSC) [38]. All interconnections between BSC and MSC (A-interface), as well as MSC and the various databases, employ CCITT Signaling

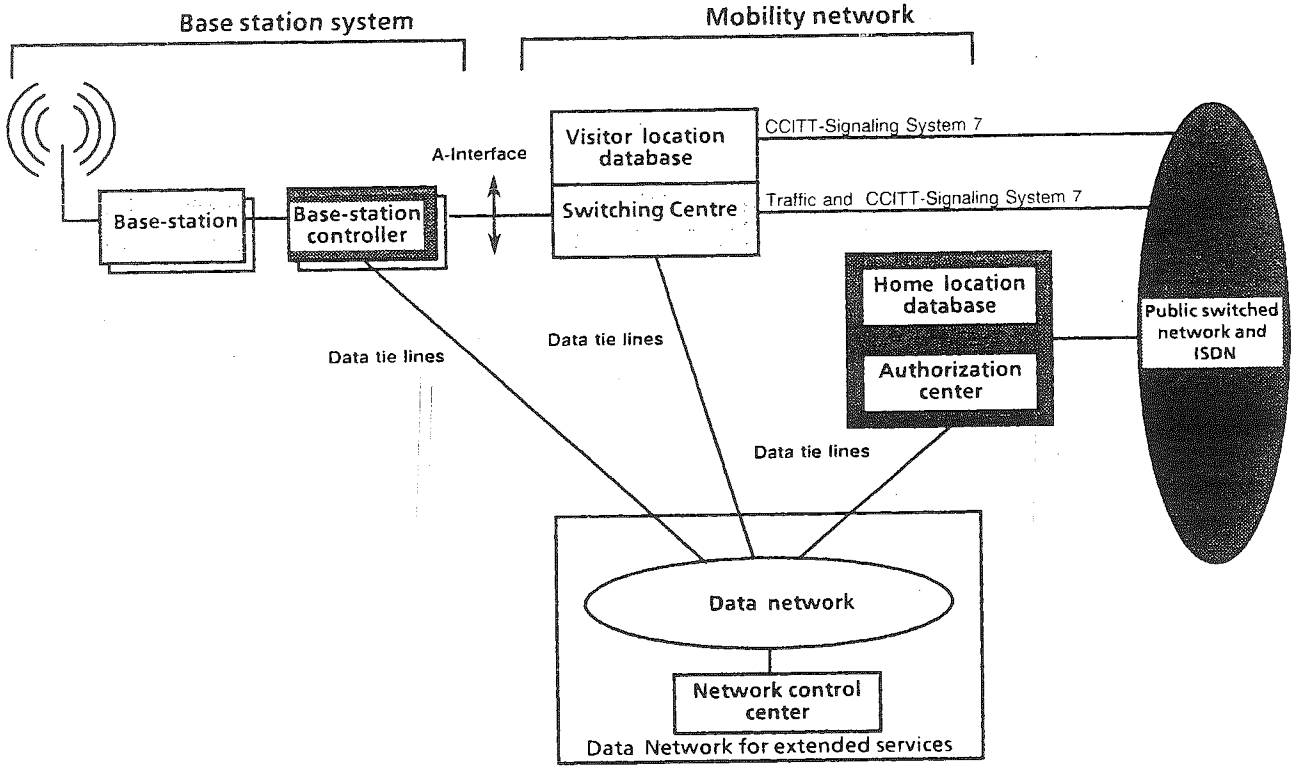

Figure 11.2 GSM architectural model for a public land-mobile-network. (Source: Ballard and Verhulst)

System 7 [39]. The MSC represents the key element of the cellular system: it routes traffic and signaling within its own network; performs handoff and roaming; and handles the signaling and traffic with other networks, such as the PSTN, ISDN, and circuit and packet-switched data networks. It should be noted that GSM has been designed to interface with an ISDN environment, and to utilize additional ISDN bearer, tele-, and supplementary services. It is furthermore noteworthy that although the GSM bearer-channel Bm/Dm requires only 23/0.75 kbps, it will be fully converted, so as to use the full ISDN capacity of 2B + D channels (2 x 64 + 16 kbps).

Before a customer with an MS is allowed to use the desired service, an authentication process is performed. The procedure already starts when the MS is activated (not used), as well as at regular intervals thereafter. The respective (nonhome) MSC(v) [40] will use the unique international mobile-subscriber number IMSI to retrieve relevant subscriber information from the user's HLR and enter them into the MSC's VLR [41]. The MSC(v) then requests authentication via the AUC located in the MSC(h) of the subscriber [42]. Depending on the operator, the equipment may be verified by means of an equipment identity register (EIR). After the authentication process is concluded positively, the MSC routes the call to its destination.

In addition, the MSC performs handoff and roaming functions. Each MSC controls several cells/base station subsystems (S_i) and is therefore responsible for inter- and intra-network routing. A simple change from one cell to another cell within the same MSC is known as handoff. Generally speaking, the MSC will perform a handoff when signal strength and bit-error rate of the radio link between MS and the current BS is less optimal than between the MS and an adjacent BS. A change from a subsystem S_1 controlled by a MSC_1 to a subsystem S_2 controlled by a different MSC_2 is defined as roaming. Since GSM is a Pan-European cellular network, it is conceivable that the roaming process involves two operators in different countries (e.g., France and Germany). International roaming, however, necessitates the exchange of accounting information in order to ensure accurate billing and revenue splitting [43]. The provision of Pan-European roaming thus requires a dedicated intelligent network that is based on the CCITT Signaling System 7 [44]]. The SS7 used by GSM is referred to as mobile application part (MAP). MAP, however, is a nondedicated network that has been implemented in different ways throughout Europe, and is presently not fully tested [45]. Since this situation could lead to inefficient routing combinations, and therefore high call-charges for roaming subscribers, the GSM working group will have to address this issue [46].

11.1.2.2.3 GSM Supported Services

Aside from the initial basic-duplex telephone communication between public land-mobile-network subscribers, or between mobile users and the PSTN, there are additional services available, which can be grouped into three categories: teleservices, bearer services, and supplementary services. While teleservices currently comprise only normal telephone communications (speech), the supported spectrum will broaden to support services such as short messages to the mobile stations, access to message-handling system according to CCITT X.400, and group 3 facsimile [47].

Bearer services provide users with a wide array of data-communication services to access data-processing and storage facilities located outside the GSM network [48]. Services will include circuit-switched data communication in asynchronous and synchronous mode, with speeds between 300 baud and 9.6 kbps, and interworking with the PSTN as well as ISDN [49]. Moreover, subscribers will be able to use synchronous, packet-switched data transmission with speeds between 2.4 kbps and 9.6 kbps [50]. Data services are offered in so-called transparent and nontransparent modes. In contrast to the transparent data services, where error correction is limited, nontransparent data services employ a GSM defined radio-link protocol to achieve error-free, though reduced (<= 4,8 kbps), throughput [51].

The supplementary service category, as defined by GSM, supports a variety of advanced functions such as call forwarding, call barring, call holding, and call waiting. While GSM's supplementary services follow the ISDN model in principle, it represents a somewhat reduced subset since various services available for terrestrial use appeared irrelevant for the mobile communications environment [52].

11.1.2.3 European GSM Implementation Strategy

Article 1 of the Memorandum of Understanding, which has been signed by 22 organizations in 18 countries, stipulated that the signatories will commence commercial service by July 1991. Notwithstanding, only network operators from Denmark, Finland, and Sweden, demonstrated pre operational GSM networks on July 1, 1991 [53]. Other GSM operators announced delays of up to one year before they started providing services. It is important to distinguish between two categories of problems, both of which adversely impact the pace of implementation of the Pan-European digital cellular network. First, technical problems that affect all GSM operators equally and second, country-specific factors that lead to a deliberate or intended delay of the GSM roll-out process. The most significant technical obstacle responsible for the holdup of the beginning of the service was the GSM standard itself. Since the standard work was still in flux as of July 1991, manufacturers were reluctant to produce equipment, and thereby run the risk of having to call back terminals to alter the software [54]. Also affected by the nonstabilized GSM standard were manufacturers of test and measurement equipment.

Aside from technical problems, there are considerable differences among the signatories of the MoU regarding the vehemence with which the construction of the GSM infrastructure is pursued. One important aspect is the competitive environment. According to Table 11.7, the relative competitiveness is characterized by the number

Table 11.7
The Competitive Environment of the GSM System in Selected European Countries

	GSM Operators	
	One[a]	*Two or More*[b]
Operators: One	A: Austria, Belgium, Ireland, Italy[c], Luxembourg, Spain, Switzerland	B; Finland, Germany, Norway, Denmark, Netherlands, Portugal, U.K.[d]
Two or more	C: None	D: France, U.K.. Sweden

[a]Whether a second license will be awarded or not will be determined by the appropriate authority (PTT/Government).

[b]Second license will be assigned but not yet awarded.

[c]Italy's antitrust commission has backed proposals for a second GSM license, thereby ending SIP's current monopoly. Notwithstanding, there will be no government decision on the issue of a second GSM license prior to November 1992.

[d]Two licenses have been awarded to Cellnet and Vodafone in the United Kingdom.

of analog operators (one or more) and the number of present, and future, GSM operators (also one or more).

Indeed, the licensing of a second GSM operator in countries previously served by just one operator (e.g., Germany, Portugal) signifies the first substantial step towards more liberalization in the telecommunications service market of the respective countries.

Non-PTT network operators in field-B countries obviously have the greatest incentive to speed up the implementation process. Interestingly, however, PTTs in countries grouped in field B gained competitive advantages by delaying the licensing of a second GSM operator by several months. For example, the second GSM license in Finland was awarded only in May 1990, while the second GSM network operators in the Netherlands, Norway, Denmark, France, and Portugal had not been determined as of March 1991. This provides the involved PTTs with a valuable head start, which they can use for network planning or site acquisition, for example.

There is relatively little interest in launching and promoting a GSM network in countries that do not plan to license a second network operator, such as Austria, Belgium, Italy, and Spain (field A). In fact, most of these countries greatly increased the subscriber capacity of their analog systems within the last two years, as documented in Table 11.1. In 1990, for example, Italy, Spain, and Austria introduced TACS 900 systems. Hence, a second important factor for the speed with which the GSM network will be implemented is the capacity of presently operating analog networks. In these countries (field A), the propensity to promote GSM will depend on the remaining analog capacity, although the network operators are forced to implement the GSM network in compliance with the MoU.

A third crucial factor influencing the changeover to GSM is the perceived price-performance ratio for equipment and services, relative to existing analog network(s) (see Section 11.1.1.3). As delineated in Table 11.6, the cost of using cellular telephone services is (absolutely) highest in France and Germany. Notwithstanding, it is widely expected that GSM terminal prices will initially be higher than analog equipment in already high-priced countries such as Germany and France [55]. However, given the size of the market and the number of manufacturers participating in it, a rapid decrease in the price of equipment is likely. The Pan-European GSM network will eventually provide international roaming as well as new bearer and supplementary services. Table 11.8, however, illustrates the fact that most GSM networks are offering only limited coverage around highly populated areas in the beginning.

According to the information compiled in Table 11.8, it will take well into 1994 or 1995 before full international roaming is available. Especially between 1992 and 1993, the GSM coverage will not reach beyond major metropolitan areas. Potential limitations regarding the quality of the service provided by the GSM networks, however, are not just confined to the coverage, but also encompass product availability. Although the MoU explicitly emphasized the importance of handheld terminals, various technical problems will significantly delay the introduction of equipment that is comparable to existing analog products in terms of size, weight, and performance until well into 1993.

11.1.3 Conclusion

By the end of 1990, almost 3.5 million subscribers were using cellular services in 11 EC countries, 6 EFTA countries, and Sweden. These services were provided by 8 incompatible analog-cellular systems, which is why roaming is presently only possible within two areas: the four Scandinavian countries (Denmark, Finland, Norway, and Sweden) and Belgium, Luxembourg, and the Netherlands. In order to eliminate the wasteful duplication of R&D expenses and offer roaming services throughout Europe, all market participants eventually agreed to an open second-generation digital cellular system standard—GSM. The Pan-European GSM network and the presently operating analog systems are completely independent, and also use different frequency bands. Hence, GSM terminals are only capable of accessing the digital network, and there will be no dual-mode phones. Significant economies of scale are realizable since equipment adhering to one standard is marketable in 17 European countries, all of which signed the GSM Memorandum of Understanding. Aside from these advantages, the GSM network is assumed to be spectrally up to ten times more efficient than analog systems, thus offering an equally larger network capacity.

Table 11.8
GSM Infrastructure Development in CEC and Other Selected European Countries

		Coverage		
Country	*Operator*	*Start*	*End (1992)*	*Total*
Austria	PTT	12/91	Vienna and airport	1995
Belgium	RTT (PTT)	1/92	Full coverage	1992
Denmark	TD (PTT)	92	Metropolitan areas and freeway	1995
	2 Operator	—	—	—
Finland	TF. (PTT)	09/91	10 Metropolitan areas and connecting routes	1995
	Radio Linja	12/91	10 Metropolitan areas and connecting routes	1995
France	FT (PTT)	2/92	Most metropolitan areas	1995
	SFR	—	—	—
Germany	DBP T. (PTT)	8/91	50%	1994
	Mannesmann	8/91	80%	1994
Greece	PTT (68%)	12/92	Athens and airport	1997
Ireland	Eireann (PTT)	1993	Dublin and airport	1996
Italy	SIP (PTT)	10/92	Metropolitan areas	1994
Luxembourg	PTT	1993	National coverage	1992
Netherlands	PTT	1992	Amsterdam and airport	1994
	2 Operator	—	—	—
Norway	PTT	02/92	Oslo and airport	1995
	2 Operator	—	—	—
Portugal	(CTT/TLP)	1992	Lisbon and airport	1996
	PTT	—	—	—
	2. Operator			
Spain	Telefon. (PTT)	03/92	Barcelona, Seville, Madrid	1994
Sweden	ST (PTT)	11/91	Ten largest cities	1994
	Comvik	02/92	—	—
	Nordictel	—	—	—
Switzerland	PTT	10/92	Geneva and airport	1995
U.K.	Cellnet	> 94		—
	Vodafone	10/91	80%	12/93

Source: "Internationale GSM-Planung im Ueberblick," Mobilfunk 2 (Juni 1991): 8-9.

The uniqueness of the GSM systems roll-out is not only confined to the fact that it will be disseminated in all EC and EFTA countries. Indeed, the introduction of the GSM system is accompanied by a fundamental change with regard to the provision of telecommunications services in numerous European countries. Previously monopolistic PTTs have begun liberalizing the market for value-added services. As a consequence, countries like Germany, Finland, Norway, Denmark, Portugal, and the Netherlands, have for the first time issued a second license for the operation of a GSM system, in direct competition with the national PTTs. Notwithstanding, the pace with which the GSM system is introduced within each country differs markedly. As delineated, countries with presently only one analog cellular-telephone network, but two licensed GSM operators, are likely to see the fastest implementation of the new Pan-European digital network. Based on experiences in the United Kingdom, it can be concluded that countries adopting a two-tier service structure are likely to see a rapid and aggressive expansion of their subscriber base. In summary, it can be said that GSM represents at the present time the most spectrum-efficient, homogeneous, and fraudproof cellular system in the world.

11.2 PUBLIC MOBILE RADIO

11.2.1 Regulatory Aspects

As in the United States, mobile communications was first made possible in Europe by the introduction of mobile radio systems. Traditionally, mobile radio systems in Europe were privately built and operated. The underlying architecture of these installations consisted of one or more base stations and one or more mobile-handsets (so-called first-generation mobile radio). For the larger part, these conventional private mobile-radio (PMR) systems provided only limited coverage, since most companies could not afford to install and maintain multiple base stations [56]. Furthermore, as pointed out in Section 5.4.3, PMRs are significantly less spectrum-efficient than trunked mobile-radio systems. In view of the severe spectrum shortage especially in metropolitan areas, an ever-increasing number of users have to share channels, which in turn leads to a degradation in service quality. Hence, several regulatory authorities in Europe are actively encouraging the development of trunked mobile-radio technology in general and publicly operated trunked mobile-radio systems in particular (second-generation mobile radio) [57]. The various operator/technology combinations are systemized in Table 11.9.

Unfortunately, the terminology associated with the mobile radio service provision currently used is open to more than one interpretation. While the classification conventional versus trunked mobile radio is widely accepted, an unambiguous differentiation according to the provision of mobile services has yet to be established. Thus, the distinction between private access and public access mobile-radio systems is

Table 11.9
Mobile Radio Service Provision and Technology Combinations

Type of Operation and Access	*Technology*	
	Conventional	*Trunked*
Private	Conventional private mobile radio systems (CPMR)	Trunked private mobile radio systems (TPMR)
Public	—	Trunked public access mobile radio systems (TPAMR)

introduced. In contrast to conventional and trunked PMR systems, which may only be used by one or a restricted number of professional users, public-access mobile radio (PAMR) is used by a large number of individuals. PAMRs differ from TPMRs and CPMRs in that the infrastructure is installed and maintained by a service provider, who is reselling system capacity for a premium. Consequently, a subscriber to PAMR services does not have to apply for a license.

The first trunked PAMR system in Europe was introduced in 1987, in the United Kingdom [58]. In 1986, the Department of Trade and Industry (DTI) began awarding licenses for two national and ten (of the twenty) regional-trunked PMR in the middle subband of Band III (175 to 225 MHz) [59]. Five of the twenty regional operators were to provide services for the London area [60]. Each of the national operators were assigned 100 channels [61], while each regional operator received 20 channels [62]. The actual start of the PAMR service, however, was delayed because of problems associated with the drafting and manufacturing of standard-conforming equipment. Once these initial problems were solved, the apparent lack of demand for PAMR services led several licensees either not to commence with the installation of the network, or return their license to the DTI [63]. In one case, the DTI revoked the license of an operator in the London area because of failure to start operations [64]. As a consequence, two firms will offer national services and seven companies will provide regional PAMR services in the United Kingdom. Three of the regionally-operating firms are in the London area [65], and only one of them has actually started operations [66].

In addition to the above-described activities, the DTI is also allocating new spectrum for common base station services (CBS) [67]. CBS systems provide services similar to TPMR, but are cheaper and not quite as sophisticated [68]. A CBS typically comprises one base station with a range of approximately 30 miles or less and utilizes three voice channels, on average. The DTI plans to allocate 16 new channels as well as 20 geographically restricted channels for CBS [69]. Since CBS systems operate only within a limited area, the underlying reuse allocation scheme allows the addition of more than 36 new licenses to the already awarded 684 CBS licences. To ensure that these licenses are used properly, the DTI is enforcing tighter loading requirements. Indeed, 18 months after the licenses are awarded, operators have to have at least six users and 50 mobile terminals [70]. The DTI perceives the relationship between trunked PMR and CBS as complementary rather than conflictive. While CBS is significantly less spectrum-efficient when compared to trunked technology, the DTI wants to restrict its applications to a one-base-station single-channel configuration, suitable only for small companies with limited coverage requirements [71].

Besides the United Kingdom, there are several other countries progressing toward the introduction of PAMRs. In January 1990, the DBP Telekom, for example, began operating its PAMRs known as ''Chekker networks,'' covering major economic centers in Germany. Nine months later, in October 1990, the ministry of telecommunications commenced on accepting applications for various types of regional and national TPMR and PAMR licenses. In a first round, the ministry awarded 6 of 28 planned type-A licenses in April 1991, which legalizes the operation of PAMR in densely-populated urban areas [72]. By August 1992, a total number of 9 private licensees operated in 14 markets [73]. Type B licenses, on the other hand, include all remaining areas whereby the coverage of the system must be less than 15.000 square kilometers per license. Systems operating under license B may not be connected to an A-licensed system, unless an A-type operator is applying for it. The issuance of B-type licenses will not begin prior to the completion of the type A licensing-process. Type C licenses are reserved for private trunked mobile-radio systems (TPMR), which are installed in locations such as airports [74]. In contrast to A and B systems, operators of C-type networks are not permitted to offer public services. Finally, one D-license for a nationwide data PAMR will be awarded by the Ministry of Telecommunications at the end of 1991.

In France, the Direction de la Reglementation began the first license-award process for 6 trunked PAMR licenses in October 1989 [75]. The ministry received 37 applications from 11 consortia for the 4 coverage areas (Nice, Marseille, Quimper, and Nantes), and announced the 6 winners in February 1990 [76]. Under the provisions of the license, each operator's system must be analog and comply with the MPT 1327 protocol, which will be delineated further below [77]. Although all networks will consist of multiple base stations, no more than 6 channels may be used for each single one, and 25 channels for the entire system [78]. In March 1991, the Ministry concluded its second round in the licensing process, in which it awarded 15 licenses for public access trunked mobile-radio systems for 7 regions: Clermont-Ferrond, Bordeaux, Montpellier, Toulouse, Lyon, Rennes and Poitiers [79]. In contrast to the initial 6 licenses issued, these 15 are 10-year instead of 5-year licenses, and operators may use up to 40 channels rather than 25.

Other European countries have not yet progressed so far. In Italy, for example, SIP had to delay the start-up date for its trunked PAMR system, while the licensing process for two pilot systems, in Bologna and Venice, has not yet been finalized by the Ministry of Post and Telecommunications [80]. In Spain, the government intends to award 22 ten-year PAMR licenses in 11 areas: Madrid, Barcelona, Valencia, Seville, Bilbao, Santiago, Asturias, Malaga, the Balearic Islands, Las Palmas, and Tenerife [81]. But the government has so far failed to stipulate the conditions under which these licenses will be issued. Moreover, it appears that, due to the lack of available spectrum, no more than 3 operators may be licensed prior to 1995 [82]. Portugal commenced with the allocation procedure for 10 PAMR licenses in 4 regions; the 2 state-owned telephone companies—Telefones des Lisboa e Porto (TLP) and Correios e Telecommunicacoes (CTP)—will also receive licenses for areas where they provide wired-network services [83].

While all the above-mentioned countries liberalized their markets for the provision of PMR services, Belgium and the Netherlands have no such plans. In the Netherlands, the only PAMR system will be operated by the PTT in Amsterdam, Rotterdam, Utrecht, and The Hague [84]. Likewise, the Belgian PTT Belgacom—formerly Regie de Telegraph et Telephone (RTT)—is going to be the sole operator of PAMR systems in Brussels, Ghent, Charleroi, and Liege [85]. Yet other European countries, such as Denmark and Ireland, will be without PAMR services entirely.

11.2.2 Market Aspects

In 1988, the users of private mobile-radio systems were by far the largest group within the entire European mobile-communications community. As Table 11.10 shows, some 2.63 million people were using private mobile-radio networks.

As delineated above, the most highly two populated countries, Germany and the United Kingdom, contain more than one-third of all PMR users in Europe. However, it also becomes apparent that consonant to the diffusion of cellular technology, the 4 Nordic countries (Norway, Sweden, Finland, and Denmark) have the highest penetration of PMR users. More particularly, while Germany and the United Kingdom have only 9 or 10 PMR users per 1,000 population, Norway has 39.

With regard to the overall PMR equipment sales in Europe, it becomes obvious that the market potential for each country is largely determined by the size of its population, the penetration rate, and the price.

The latter factor is responsible for the fact that the French equipment market ranked behind that of the United Kingdom but before Germany, as illustrated in Figure 11.3. It also should be noted that the top three markets—Germany, France, and the United Kingdom—are responsible for over 50% of the total PMR equipment sales in Europe. Viewed overall, these figures indicate that the various European nations show significant differences regarding the pace with which PMR systems are accepted.

Table 11.10
PMR Users in the EC, EFTA Countries, and Sweden

Country	*PMR Users (thousands)*	*Penetration per 1,000*	*Country*	*PMR Users (thousands)*	*Penetration per 1,000*
Sweden	210	26	Netherlands	206	15
Norway	155	39	France	240	4
Finland	81	17	Belgium	112	11
Iceland	N/A	N/A	Italy	142	3
Denmark	81	17	Germany	600	10
U.K.	500	9	Luxembourg	N/A	N/A
Switzerland	79	11	Spain	95	3
Austria	130	17	Portugal	N/A	N/A
Ireland	N/A	N/A			

Note: N/A = not available.
Source: Commission of the European Communities, The Market and Key Factors Affecting the Nature and Development of PAN European Mobile Communications Post-1995, 17.

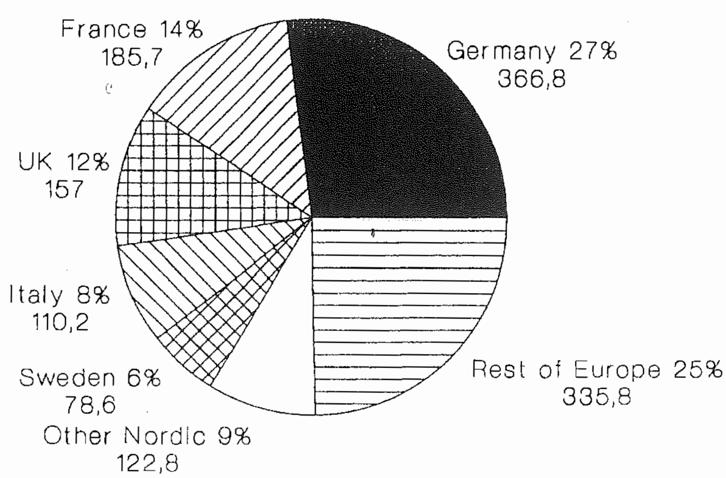

Figure 11.3 European PMR equipment sales, 1988 (in $ millions). (Source: Frost and Sullivan)

11.2.3 Technological Aspects

As described above, there are two major factors influencing the present PMR environment in Europe: the deregulation of the market, and the availability of new technology. As a consequence of the steadily growing number of both private and nonprivate PMR [86] users, regulators across Europe are increasingly effecting the implementation of spectrum-efficient analog trunking technology. Of particular importance is the transition from privately operated PMR toward trunked public-access mobile-radio systems. While proprietary standards were acceptable for traditional mobile systems, it is obvious that trunked PAMRs, operated by PTTs as well as independent organizations, require a well-defined standard. Hence, the standard network protocol MPT 1327 for trunked PAMRs was issued in the United Kingdom and made mandatory for all systems operating in the U.K. Band III.

At the core of the MPT 1327 standard is an access protocol, which ensures that the signaling channels for the call set-up are used as efficiently as possible [87]. Moreover, it is important that signaling systems are robust, and remain stable and operational in situations where there are far more call requests than available channels. In order to achieve these objectives, MPT 1327 uses a dynamic frame-length technology (slotted ALOHA). A control channel is comprised of slots, each 128 bits long (107 ms) [88]. Apart from information for other terminals, each slot has an ALOHA number, specifying the number of consecutive slots sufficiently long to send a call request [89]. Given these properties, the MPT 1327 protocol is similarly suitable for single site, regional, multiregional, national, and multinational systems.

It should be noted, however, that the MPT 1327 is just one signaling protocol among many. Indeed, other quasi-standardized access protocols, such as Radiocomm 2000 and Mobitex, as well as several proprietary protocols, are employed throughout Europe. Notwithstanding, PAMRs in France and Germany comply to a large extent with MPT 1327 [90]. In Germany, however, substantial changes have been made to the air-interface specification MPT 1343. Instead, a so-called ZVEI-RegioNet 43 standard was issued and consequently employed for the regional PAMRs (Chekker networks) operated by the German DBP Telecom [91].

Concerning the degree to which analog PMR systems are specified in various European countries, it can be concluded that the specifications are minimum requirements, and not comprehensive standards. In order to create a Pan-European standard for digital-trunked PMR systems, ETSI set up a new Sub Technical Committee Radio Equipment and Systems—STC RES 6 [92]. It is planned that an I-ETS for digital trunked PMRs be completed by 1992 and an ETS by 1995. The standardization work includes the definition of signaling protocols, air interfaces, network configuration, and demands on frequency spectrum.

11.3 MOBILE RADIO DATA NETWORKS

A detailed description of mobile radio data networks (RDNs) and their respective advantages have been outlined above, in Sections 4.2.3 and 8.3. In Europe, ETSI's Sub Technical Committee TC RES 6 is charged with defining a standard for packet switched, burst-mode mobile data transmission. In addition, it was suggested that RES also issue an I-ETS/ETS for mobile telemetric devices on the basis of an already existing CEPT recommendation (T/R 20-03 and 20-04).

Despite the absence of RDN standards, there are two different proprietary systems being installed in several European countries [93]. In the United Kingdom, for example, two operators—Hutchison Telecommunications and RAM Broadcasting—are installing mobile data networks, while the two other licensees suspended their operations (Cognito) or, respectively, handed back their license (Motorola). The RAM Mobile Data network is supported by France Telecom (20%), and the Swedish PTT (5%) and is based on Mobitex technology for which, however, there are presently no portable terminals available [94]. Other Mobitex networks are already installed in Sweden, Finland, and Norway. The second system, based on a proprietary technology (Motorola), is used for the second RDN in the United Kingdom as well as the German RDN, operated by the PTT. Interestingly, the German PTT only decided to install the system after the manufacturer agreed with the issuance of the air-interface protocol. Which of the two system technologies may eventually be converted into a European standard depends, inter alia, on the question of whether or not the companies will forgo their intellectual property rights and make the standard fully open to other competitors.

11.4 PAGING SYSTEMS

11.4.1 National Paging Systems

With the exception of the United Kingdom, public paging services are presently provided by monopolistically operating PTTs. The fact that each PTT favored its respective national manufacturer accounts for the disinclination to create a European paging standard. Instead, a variety of second-generation paging systems, based on proprietary digital formats, were launched in the early 1970s. These systems were superior to first-generation systems in that they allowed the transmission of numeric messages and, furthermore, offered significantly higher performances. Instead of delivering two pages per second (two-tone sequential) as first-generation systems did, these systems were capable of broadcasting five pages per second (five-tone sequential) [95]. Notwithstanding these advantages, however, deviations in coding formats not only locked paging operators into procuring radiopagers from one manufacturer only, but also restricted the use of equipment to one European country.

In an attempt to establish a paging system that could be operated throughout Europe, CEPT created a paging standard called Eurosignal, in 1970. So far the Eurosignal system is only supported in Germany (1974), France (1975), and Switzerland (1986). Each country is divided into several zones, in which one of four possible frequencies in the 87 MHz band are reused. While Switzerland has only one zone and Germany three, France is composed of six paging areas. A Eurosignal pager supports the transmission of exactly four numbers (1,2,3,4). Hence, the inherent meaning of the number has to be previously defined between caller and receiver of the page. Moreover, the caller has to know the approximate location of the receiving person, since every broadcast area (zone) has a different PSTN access number.

The third generation of European paging systems was based on the POCSAG (Post Office Code Standardization Advisory Group) signaling scheme (now adopted by the CCIR as Radiopaging Code No 1 (RPC1)—see Section 4.2.4). In contrast to its predecessors, POCSAG supports tone-only, numeric (four-bit coding), and alphanumeric paging (seven-bit coding). POCSAG allows more than 2 million pagers per channel. Although early systems operated on a 512 bps signaling scheme, recent systems (see Section 11.4.4, below) are based on 1200 bps. Regardless of the employed signaling scheme, almost all POCSAG systems in Europe operate in the 150 MHz - 170 MHz frequency band, but are nevertheless incompatible. Table 11.11 delineates presently operating national paging systems in selected European countries.

11.4.2 Multinational Paging Systems

11.4.2.1 Euromessage

After the decision in favor of a single Pan-European standard for cellular mobile-telephone systems, the question arose whether a similar standard could also be established for paging systems. Since two new paging services based on the same technology were planned to be launched in France in 1987, and Germany in 1988, both countries commenced on negotiations, which soon included the United Kingdom and Italy.

In September 1988, a Memorandum of Understanding was signed in Paris [96] in which operators of all four (later five) countries (see Table 11.12) agreed to network their respective systems, called Euromessage. It is important to realize that various networks, such as Cityruf and Alphapage, do not provide national coverage. Indeed, the Euromessage system that operates on two different frequencies in the 460 MHz band only covers major economic centers in the four European countries involved. In the United Kingdom, for example, service will initially be confined to London [97]. Nevertheless, it is possible to send messages—tone-only, numeric and alphanumeric—to all five countries via national gateways. It should be noted that the

Table 11.11
Presently Operating National Paging Systems in Europe

Country	*System*	*Start*	*Capacity (thousands)*	*Frequency (MHz)*	*Tone*	*Numeric*	*Alpha-numeric*
Germany	Eurosignal	1974	300	87	X		
Denmark	POCSAG	1983	90	469		X	
Finland	POCSAG	1985	100	146	X	X	
	Golay	1978	N/A	450	X	X	X
Greece	POCSAG	1987	200	155	X		
Italy	POCSAG	1981	1000	161	X	X	X
Austria	POC	1988	220	162	X	X	X
	OPR1						
	Golay	1975	54	162	X		
Netherlands	POCSAG	1987	200	164	X	X	X
	Golay	1978	120	87	X		
Norway	POCSAG	1984	100	148	X	X	X
Spain	analog	1972	16	160			
Sweden	POCSAG	1985	160	170	X	X	X
	RDS	1978	300	87	X		
Switzerland	POCSAG	1986	160	147	X	X	X
	Eurosignal	1986	N/A	87	X		
	Ortsruf A	1982	N/A	147			
	Autoruf	1958	N.A.	87			
U.K.	POCSAG	N/A	N/A	N/A	X	X	X

Source: Gusbeth, Mobilfunk, 41; J. Walker (Mobile Information Systems), 39.

Table 11.12
The Euromessage System

Country	*System Name*	*Operator*
Germany	Cityruf	DBP Telekom
France	Alphapage	France Telecom/ Telecoms Sys Mobile
Italy	Teledrin	SIP
U.K.	Europage	Hutchison
Switzerland	N/A	Swiss PTT

Euromessage service in the United Kingdom was planned to be provided by a consortium comprising six companies: Aircall, British Telecom, Digital Mobile Communications, Inter-City Paging, Milicom, and Racal Telecom. However, in November 1991, Hutchison Paging took over Milicom and bought out the other shareholders.

11.4.2.2 ERMES

Since the Eurosignal system was implemented in only three European countries, CEPT revived the discussion about a Pan-European digital paging system. The CEPT task force R 35 began with the standardization of ERMES (European radio message system). After the establishment of ETSI, the work was subsequently taken over by ETSI's technical committee ETSI TC PS.

ERMES enjoys the strong support of the European Community. As with GSM, the CEC adopted a Recommendation for the ERMES service and a Directive for the allocation of frequencies [98]. According to the Council Recommendation the service should have become available by December 1992, and at least 80% of the population should be covered by 1995 [99]. In contrast to the frequency allocation for GSM, the CEC Directive determined sixteen different frequencies in the 169.4 to 169.8 MHz band, with an option for an additional 400 kHz after 1992. As a consequence, the equipment requires a far more complex design than pagers that operate on only one frequency. ERMES differs from Euromessage in that it is intended to provide paging service throughout Europe, and not just around selected populated centers. Accordingly, the code capacity was enhanced to 32 million per country, whereby up to 8 potential service operators may each assign 4 million identification numbers.

In light of the total system capacity, ERMES necessitates a significantly higher transmission speed. After testing various alternatives with different channel bandwidths (12.5 kHz and 25 kHz), the TC PS committee opted for a 6250 bps transmission scheme. It is important to realize that all aspects of ERMES, including radio interface and system architecture, are standardized. More particularly, the ETSI TC PS has 4 subtechnical committees (STC): STC PS1 defines ERMES services and facilities, STC PS2 specifies the ERMES radio subsystem, STC PS3 focuses on ERMES network aspects, and STC PS4 is concerned with the validation of the ERMES standards [100]. ERMES incorporates a number of enhanced mandatory features, which may or not be implemented by the system operator. These are prioritization of calls, broadcasting messages at specific times, and group calls. The wide range of optional features should provide operators with the opportunity to differentiate themselves in the market. Besides, there are a number of mandatory services such as international roaming and message numbering.

In February 1990, representatives of 8 countries signed the ERMES Memorandum of Understanding [101]. They were, Luxembourg PTT, Telecom Finland, DBP Telecom, Eirpage/Telecom Eireann (Ireland), Belgium RTT, Swedish Telecom Radio, Telefonica (Spain), and 2 of the 6 U.K. paging operators awarded a national license. In addition, 9 other countries—France, Turkey, Italy, Denmark, Norway, Portugal, and Switzerland—formally announced their intention to sign the MoU [102]. Hence, virtually all important European countries support the introduction of ERMES.

By the middle of 1992, a total of 26 operators in 18 countries had signed the MoU. Notwithstanding, it became clear that none of them will be able to meet the January 1, 1993 deadline for starting the service. There are two major reason for this delay. First, neither Germany's Ministry for Posts and Telecommunications nor France's DRG had awarded licenses by the end of October 1992, while, at the same time, U.K. paging operators still had ample capacity on existing analog paging networks. This caused manufacturers to take a cautious stance on mass-producing ERMES pagers, which, in turn, further undermined the confidence of operators.

11.4.3 Market Aspects

The number of subscribers to paging services in Europe is comparatively low, and varies significantly between the various countries. As Table 11.13 delineates, the United Kingdom has the largest number of paging subscribers in absolute terms, while the Netherlands and Norway show the highest penetration rate.

A comparison of growth rates of the number of paging subscribers over a two year period reveals that the U.K. market remained stagnant. Among the more populated European countries, Italy had the largest increase percentage-wise (150%), while Germany had the highest gain in absolute numbers (125,363). Other countries that performed above the average growth rate of 39.6% were Ireland (107%), Belgium (105%), Netherlands (51%), and Luxembourg (50%).

11.4.4 Technical Aspects

During the last 20 years or so paging technology has made substantial progress with regard to spectrum efficiency, and therefore system capacity. Essentially, this was made possible by the transition from analog to digital transmission schemes. Analog tone-only or voice-tone pagers required approximately 7 seconds per page, plus an additional 10-20 seconds for the message. Early digital pagers, in contrast, could broadcast about 5 alphanumeric messages per second [103]. With the introduction of POCSAG and the following increase of transmission speed from 512 baud to 1200 baud and, finally, 3250 baud (ERMES), system capacity could be steadily increased.

Consonant with this development, paging systems are increasingly operating in higher frequency bands. While early systems such as the Eurosignal system, for example, use the 90 MHz band, new high-capacity systems designed for regional coverage (e.g., Euromessage) operate in the 470 MHz band.

Table 11.13
The Development in Number of Subscribers of Paging Services in EC/CEPT Countries between 1989 and 1991

Country	Subscribers as of 9/89	Subscribers as of 9/91	Penetration of population (in thousands)	Growth Rate (%)
Austria	68,615	82,544	10.86	20.3
Belgium	59,345	121,767	12.29	105.2
Denmark	38,200	48,772	9.49	27.6
Finland	32,100	40,450	8.14	26.0
France	168,600	220,086	3.92	30.5
Ireland	3,608	7,500	2.11	107.9
Italy	43,500	108,759	1.89	150.0
Luxembourg	2,791	4,183	8.37	49.9
Netherlands	194,000	293,000	19.66	51.0
Norway	63,487	83,771	19.94	31.9
Spain	10,237	11,911	1.14	16.3
Sweden	113,100	126,206	14.85	11.6
Switzerland	29,767	39,884	6.04	33.8
U.K.	645,000	669,000	11.67	3.7
Germany	194,284	319,647	4.09	64.5
Total	1,619,434	2,260,891	6.19	39.6

Source: "Subscribers to European Cellular and Paging," FinTech Mobile Communications 40 (September 1989): 2. "Mobile Communications Guide to European Mobile Subscribers," FinTech Mobile Communications 86 (September 1991): 5.

Although ERMES operates in the 170 MHz band, pagers will require far more complex technology than any previous paging generations. One reason is that no single common frequency band was identifiable for ERMES services within all European countries. Hence, 16 different channels had to be determined. This in turn, requires that the paging receiver be frequency agile. While all former pagers operated on single frequencies, and therefore employed crystal oscillators using either dual, superheterodynes or homodyne techniques, frequency-agile pagers necessitate the use of synthesizers [104]. Another factor adding to the design complexity is the high transmission speed of 3250 baud. In order to ensure reliable performance, ERMES employs a 4-level FSK modulation scheme and low-noise discriminators [105].

As delineated, in principle, in Section 9.2 [106], increased coverage and capacity will lead to a shift in complexity from the radio side to the transmission network. With regard to paging systems, two groups of transmission are in use: "real-time transmission" and "store and forward." In real-time transmission, identical messages have to be broadcast at the same time by all base stations with overlapping coverage. Early paging systems required only modest transmission speeds, which the PSTN network and low speed modems could cater to. However, ERMES makes the use of fixed radio links or satellite transponders necessary in order to facilitate the timely distribution of messages to all base stations [107]. In summary, it therefore can be concluded that the high performance standards of the latest paging system not only necessitates the development of sophisticated highly integrated VLSI devices, but also entails careful reconsideration of all network aspects and components.

11.5 CORDLESS TECHNOLOGY

11.5.1 First-Generation Cordless Standards

As mentioned in Section 8.5.1, most cordless systems are presently used in domestic applications, but are increasingly being developed to operate as private branch exchanges (PBX), wireless local area networks (WLAN), or public network access points (telepoints). In the early 1980s, Europe was faced with an influx of illegal cordless products, most of them operating on frequencies used by military communications systems. In order to legitimize the European market for cordless systems, the Conference of European Posts and Telecommunications (CEPT) commenced on defining the cordless standard CEPT CT1. The CEPT CT1 standard, based on frequency division multiple access (FDMA), operates in the 914/915 959/960 MHz frequency bands and provides 40 full-duplex channels with 25 kHz width. Given the tightness of the standard and the high frequency (900 MHz) bands in which these systems operate, low-cost manufacturing of these devices appeared not feasible, resulting in an introductory price for cordless systems in 1985 of about $1,000 [108]. By mid 1992, the price level for CT1 cordless systems ranges from $700 in Italy to $350 in Germany. Hence, without regulatory protection against illegally imported low-frequency equipment, CEPT CT1 products could not prevail in the marketplace. Notwithstanding, systems based on the CEPT CT1 standard are particularly suitable for use within an indoor environment for their frequency of operation, and, furthermore provide a certain degree of security against interception. Since part of the frequencies currently used by the CEPT CT1 systems will be used for the digital European cellular mobile-communications network (GSM), a supplementary standard, CEPT 1TR2 (commonly known as CEPT 1+), was specified by CEPT in 1988. Cordless systems based on CT1+ are also analog devices based on FDMA, which operates within the 885/887, 930/932 MHz frequency bands and offers 80 channels. In contrast to the CEPT CT1 standard, CEPT CT1+ explicitly permits the interworking of equipment made by different manufacturers. The CEPT CT1 standard has been officially adopted only by six EC countries—Belgium, Denmark, Germany, Netherlands, Italy, and Luxembourg—whereas CEPT CT1+ was only introduced in Germany, Austria, and Switzerland.

Regulatory authorities in the United Kingdom, France, and Spain allow the use of nonstandardized cordless equipment, also referred to as CT0. In the United Kingdom, for example, analog cordless systems have to conform to Technical Guide 47, published by the Department of Trade and Industry (DTI), which includes similar provisions to the ones enforced by the FCC Part 15 [109]. Cordless systems satisfying the stipulations of the technical guide are operating on one of eight preset channels in the 47.44-47.55 MHz and 1.632-1.792 MHz frequency band, and are termed U.K. CT1 standard equipment, which is ambiguous in that it has nothing in common with the CEPT CT1 standard described above. In France, cordless telephones have to comply to the so-called '41-26' standard, which allows for the manufacturing of low-cost equipment. The name of the standard is derived from the operating frequencies, which are 41.375-41.475 MHz and 26.315-26.415 MHz. It is important to note, however, that despite the enforcement of standards by national PTTs (especially in CEPT countries), there is evidence of considerable penetration of illegal equipment in countries such as Italy, the Netherlands, and Germany [110] . Given the low frequency of operation, U.K. CT1 and 41-26 cordless phones, as well as illegal cordless telephones, are susceptible to various interferences such as fluorescent lightning and are, furthermore, prone to eavesdropping. In order to overcome these and other problems, a number of second-generation cordless standards have been developed.

11.5.2 Second Generation Technical Standards—CT2, Telepoint, and DECT

Based on the inherit limitations of first-generation cordless equipment, several U.K. companies began to develop digital cordless telephones. The so-called CT2 standard was officially published in the United Kingdom in 1987 as BS 6833 and MPT 1334 [111]. CT2 was primarily developed for telepoint applications, but additional cordless products for the residential and office market (WPBX) were anticipated. The acceptance of the CT2 standard, however, was severely curtailed by the fact that no common air interface (CAI) was defined. Consequently, an MS_i could only interwork with a BS_i, but not with other BS_j. Hence, a more detailed specification based on the CT2 standard was developed (CT2 CAI), and officially published in the United Kingdom as MPT 1375 in 1989 [112].

CT2 and CT2 CAI are both based on frequency division multiple access/time division duplex transmission (FDMA/TDD), employ digital speech-coding techniques, and support dynamic channel allocations. The coder chosen for CT2/CAI is a 32 kbps adaptive differential-pulse-code modulation (ADPCM) [113]. Because cordless is essentially an extension to the fixed network, processing delays have to remain within a time limit of 5 ms. Since the TDD transmission scheme already causes a delay of 1 ms in the speech path, a 32 kbps codec appeared to be the only available alternative to keep the speech processing-time within the remaining 4 ms limit [114]. With a maximum output power of 10 mW, coverage ranges from about 50m indoor, to about 200m outdoors. While other countries were more cautious regarding the acceptance of CT2 (see Section 11.5.3), the Department of Trade and Industry in the United Kingdom allocated 40 x 100 kHz channels in the 864.1-868.1 MHz frequency band for CT2.

Besides CT2 CAI, there are significant efforts underway to develop a second cordless specification. The Digital European Cordless Telecommunications (DECT) standard was initiated by CEPT in the early 1988, but the specification of DECT has been taken over by ETSI Technical Subcommittee RES 3 after the founding of the European Telecommunications Standards Institute. The RES 3 subcommittee is aided by a full-time project team (PT 10), and additional support is given by the European manufacturing industry through ECTEL and ESPA [115]. In June 1991, the complete technical DECT standard was made available for public comments. The DECT standard is comprised of two parts: a common-air-interface specification (CI), and a coexistence specification (CX) [116]. While the well-defined common air interface ensures interoperability of various MS_i with different BS_i, the coexistence specification defines core and optional features of the CI [117]. In order to gain practical experience with critical issues, such as multipath propagation and diversity requirements, a DECT testbed system has been developed and built in the United Kingdom [118]. The project is part of the U.K. Government's LINK Personal Communications Programme, and involved partners from industry and academia. Similar to the CT2 standard, DECT is intended to serve as a platform for a variety of advanced applications for cordless telephony, ranging from the residential cordless phones, over WPBX and WLANs, to public telepoints.

In contrast to the CT2 standard, however, DECT operates in the 1.88-1.90 GHz frequency band [119], using higher data rates, and therefore requiring higher peak-transmission power. While CT2/CAI are based on FDMA, DECT employs the TDMA/TDD transmission techniques, which allows the MS to operate on more than one channel. Since the total available bandwidth is 20 MHz and the DECT channel bandwidth is 1.73 MHz, the system provides 11 frequency channels with each frequency channel, in turn, offering 11 voice channels. Hence, DECT will offer 132 full-duplex channels (CT2 only 40), and offers a total channel bit rate of 1152 kbps (CT2 only 72 kbps). Besides, DECT will not only be compatible with the PSTN, but also with ISDN (voice and data), X25, and IEEE 802 networks.

Importantly, the DECT standard is fully backed by the Commission of the European Communities (CEC). In fact, the CEC argues that the full potential of the cordless technology can only be realized by "the timely and coordinated establishment of a fully harmonized DECT standard in the Community" [120]. Hence, in analogy to the above-described GSM standard procedure, the CEC proposed a Council Recommendation on the coordinated introduction of DECT in the Community, as well as a

Council Directive on the frequency bands to be reserved for DECT [121]. Both Recommendation and Directive are in the first lecture of the European Parliament, and are expected to be adopted at the beginning of 1992 [122]. Table 11.14 provides an overview of standards presently adopted, and future cordless standards to be adopted, by the 12 EC countries.

11.5.3 The Cordless Standard Debate

As is obvious from the above discussion, the Commission of the European Communities intended to promote one single second-generation digital cordless standard for all of Europe, which was expected to form the technological platform for an interoperable infrastructure comprising residential cordless phones, consumer telepoints, and WPBXs. While the CEC favored DECT, the U.K.-developed CT2 standard enjoyed a significant head start, and several European countries were already planning the roll-out of CT2 based telepoints and WPBXs. The CEC initially reacted by adopting Directive 83/189, thus imposing a standstill on the U.K. CT2 standard until July 1988

Table 11.14
Overview of Cordless Standards in EC Member States, as of June 1992

Member States	*CEPT-1*	*U.K. CT1*	*"41-26"*	*CT2/CAI*	*DECT*
Belgium	Yes	No	No	MoU/FT	Yes
Denmark	Yes	No	No	—	Yes
France	No	No	Yes	FT	Yes
Germany	Yes	No	No	FT	Yes
Greece	—	—	—	—	Yes
Ireland	No	Yes	No	Yes	Yes
Italy	Yes	No	No	MoU/FT	Yes
Luxembourg	Yes	No	No	—	Yes
The Netherlands	Yes	No	No	—	Yes
Portugal	—	No	No	MoU/FT	Yes
Spain	—	No	No	MoU/FT	Yes
U.K.	No	Yes	No	FT	Yes

Note: FT indicates ongoing field trials. MoU/FT indicates the principal intention to test cordless telepoints based on CT2 standard.

*Cordless products based on DECT may be used under the provision that the European Parliament adopts Recommendation and Directive.

[123]. Hereafter, the Commission launched the above-mentioned Directive for a 20 MHz spectrum allocation across Europe. In addition, the draft Recommendation seeks the acceptance of all EC PTTs to a memorandum of understanding, which would force the European telecommunications organizations to provide DECT telepoint services [124].

Notwithstanding these efforts, the CEC could not prevent ETSI from commencing the work on an Interim European Telecommunications Standard (IETS) for CT2, besides the already progressed DECT standard. The standard debate was further complicated during the ETSI Technical Assembly in October 1990; two manufacturers proposed the adoption of two more European cordless standards -CEPT CT1 and CT3, besides CT2 and DECT. CT3 is a proprietary standard of a Swedish manufacturer, which is technologically similar to the DECT standard. Later, however, the appropriate TC RES voted that no IETS would be developed for the CT3 and CT1 standards.

During the ETSI Technical Assembly in March 1991, the European Commission again proposed to terminate all further work on the IETS CT2 standard [125]. ETSI's Technical Assembly, however, rejected the EC proposal, thus inserting substantial uncertainty with regard to the future prospects for CT2 and DECT applications. The failure of the EC to stop IETS for CT2 illustrates the conflict of interest between ETSI and the CEC. More important, it raises questions about the CEC's ability to implement an industrial policy that guarantees a harmonized European development in the telecommunications equipment sector. As a consequence, both CT2 and DECT are official second-generation European cordless standards and will coexist for a long time to come.

11.5.4 The Cordless-Based Communications Concept

In contrast to the first-generation of cordless technology that simply provided wireless network access for residential users, second-generation cordless standards serve as a platform for a wide variety of private and public wireless services. As illustrated in Figure 11.4, one terminal equipment can be used to access the wireless private branch exchange, residential base stations, and public telepoints.

As defined in this booh, the telepoint concept addresses public communications requirements. Moreover, all three elements combined compose a personal communications system, which is why comprehensive cordless-network concepts will be discussed in detail in Section 12.2.1. The following two sections, therefore, focus on two specific cordless applications: wireless private branch exchanges, and wireless local-area networks.

11.5.5 Wireless Private-Branch Exchange

The various technological aspects associated with wireless private-branch exchanges have been delineated in Section 4.2.5.3. WPBXs developments in Europe are based on

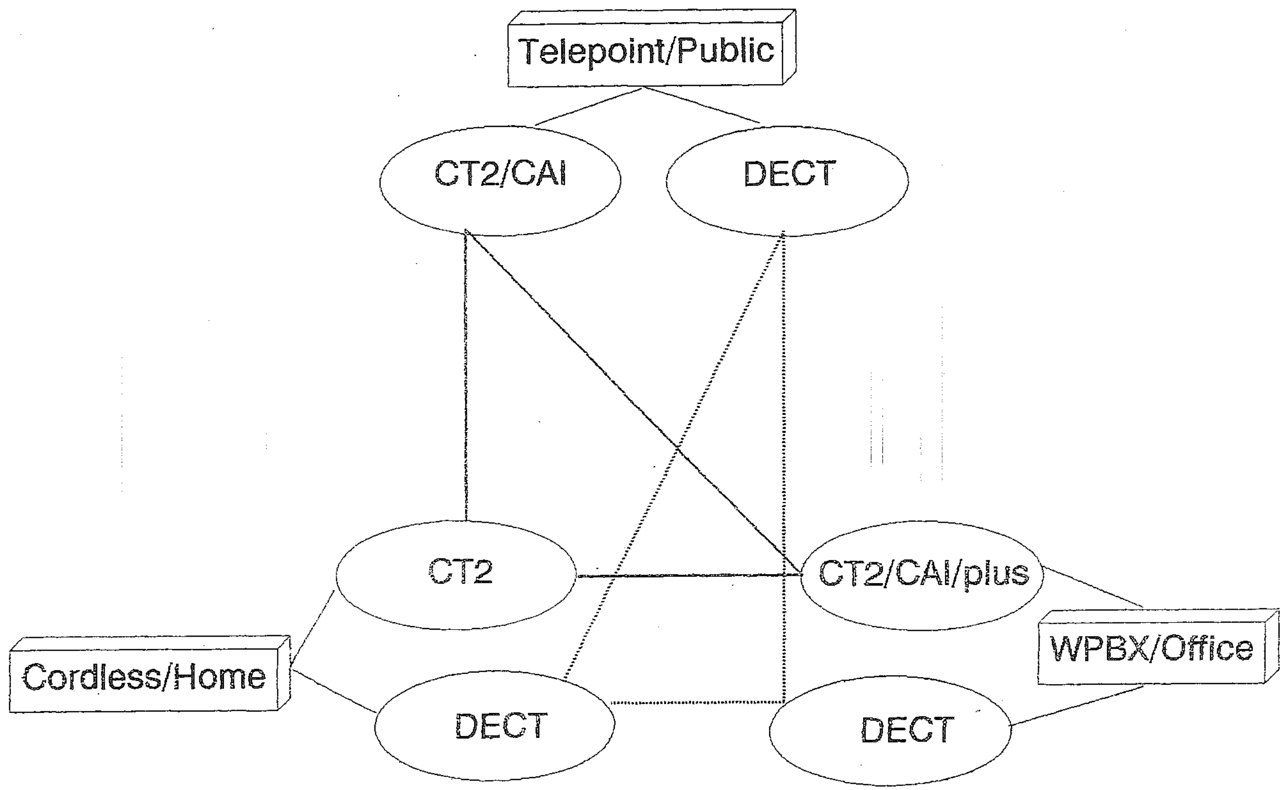

Figure 11.4 The components of a cordless-based PCN system.

CEPT CT1, CT2 and DECT technologies. While CT2-based WPBXs are currently only marketable in the United Kingdom and France, CEPT CT1 WPBX are operable in all countries that officially adopted the standard (see Table 11.3). Notwithstanding, it is reasonable to assume that DECT and CT2 will evolve as the predominant standards for future WPBX developments in Europe. Both standards are backed by large telecommunications companies. The largest European PBX manufacturers—Siemens, Alcatel, Ericsson and Philips—unequivocally favor DECT. Less well-established firms such as Northern Telecom and Motorola/Peacock opt for CT2.

It should be stressed that there are significant technical differences between CT2 and DECT, which are of direct relevance for the WPBX application. Since CT2 employs the FDMA transmission technique, there is no possibility that a user can move from one cell to another while a call is in progress. In other words, once a call is set up between the MS and the base station of a certain cell, the user has to remain within the coverage of the cell for the duration of the call. In the TDMA-based DECT system, on the other hand, the channel allocation process is dynamic. Moreover, the MS constantly monitors the signal quality of all remaining channels. Whenever certain signal parameters fall below a predefined threshold, a handover to an adjacent cell will be initiated while a call is in progress.

To achieve similar operability as DECT-based WPBXs, proponents of CT2/CAI developed an enhanced standard, CT2 Plus, for the Canadian market, which is meanwhile also supported in the United Kingdom, France, and probably Germany. [126] CT2 Plus differs from CT2/CAI in that it requires 8 MHz of spectrum-bandwidth instead of 4 MHz, thus providing far more channels [127]. In addition, substantial modifications in the signal protocol enable CT2 Plus based systems to perform cell handoff. Another major advantage inherent in the CT2 Plus architecture lies in the fact that it provides data connectivity [128]. While these enhancements make CT2 Plus and DECT PBXs more comparable performance-wise, they will also make CT2 equipment more expensive, thus undermining one of the key selling points for CT2 technology in Europe so far [129]. Judging from recent product-launch announcements [130], CT2 products, which currently feature only two channels per base station, will be more suitable for addressing moderate traffic volumes in a wider area. In contrast, DECT base stations will provide somewhat less coverage due to the higher operating frequency but will support up to twelve simultaneous conservations on a single base station, thus providing superior performance for locations with medium-to-high traffic volume.

11.5.6 Wireless Local Area Network

As delineated in Section 4.2.5.6, wireless local area networks provide two-way data services within buildings, though the range is confined to the coverage of the cell (monocell system), or multitude of cells (multicell system). According to ETSI, the

DECT cordless standard is currently the key technological platform for the provision of on-site wireless data exchange in Europe. DECT can provide variable data-bit-rates as required by the applications [131]. Specifically, DECT is capable of supporting bearer services of up to 1.14 Mbit/s (error controlled), including 144 kbps full-duplex bearer ISDN services. Since the performance is well under the level of wired local area networks (IEEE 802) of 10 Mbit/s, WLANs on the basis of DECT are only appropriate for applications requiring low to medium data rates, such as printer sharing and electronic mail.

Because of these performance limits, ETSI's propensity toward DECT is increasingly challenged by the frequency management group of CEPT [132]. In fact, several U.S. vendors of high-speed radio local area networks (see Section 8.5.5) operating at microwave frequencies are lobbying for the allocation of spectrum for their proprietary technologies. ETSI, backed by the European Commission, objects to such an allocation on the grounds that such a move not only favors U.S. companies, but also upsets plans to create a single European standard for high-speed local area networks [133]]. Instead, the standards organization commenced on establishing a new technical committee, RES 10. Its task is to develop WLAN networks with a performance of up to 20 Mbps.

Notwithstanding the ETSI and EC positions and initiatives, the Department of Industry (DTI) in the United Kingdom has allocated frequencies at 2.4 GHz for spread-spectrum-based technology, which was originally designed to operate under the Part 15 frequencies in the United States [134]. Besides, Germany and Spain have granted interim frequencies in the 18 GHz frequency band for the provision of wireless in-building networks (WIN) [135]. In light of these developments it remains an open question as to whether or not a Pan-European standard for high-speed wireless local area networks can be established, or whether each country will allocate frequencies that facilitate the dissemination of proprietary technologies.

11.6 EVALUATION OF SECOND-GENERATION MOBILE COMMUNICATIONS SYSTEMS

11.6.1 Summary of Second-Generation Systems Services

Prior to 1989, the European mobile-communications environment was characterized by a multitude of incompatible systems whose coverage was largely confined to national borders. With a few exceptions, these mobile systems were operated by national telecommunications monopolies. Despite the fact that only a few PTTs essentially controlled all aspects of mobile communications, no system was implemented that was capable of providing Pan-European voice, paging, or data services (see Fig. 11.5).

As delineated in Section 11.1, the implementation process of analog cellular-telephone-systems began in 1981, and by 1986 all EC and EFTA countries, except

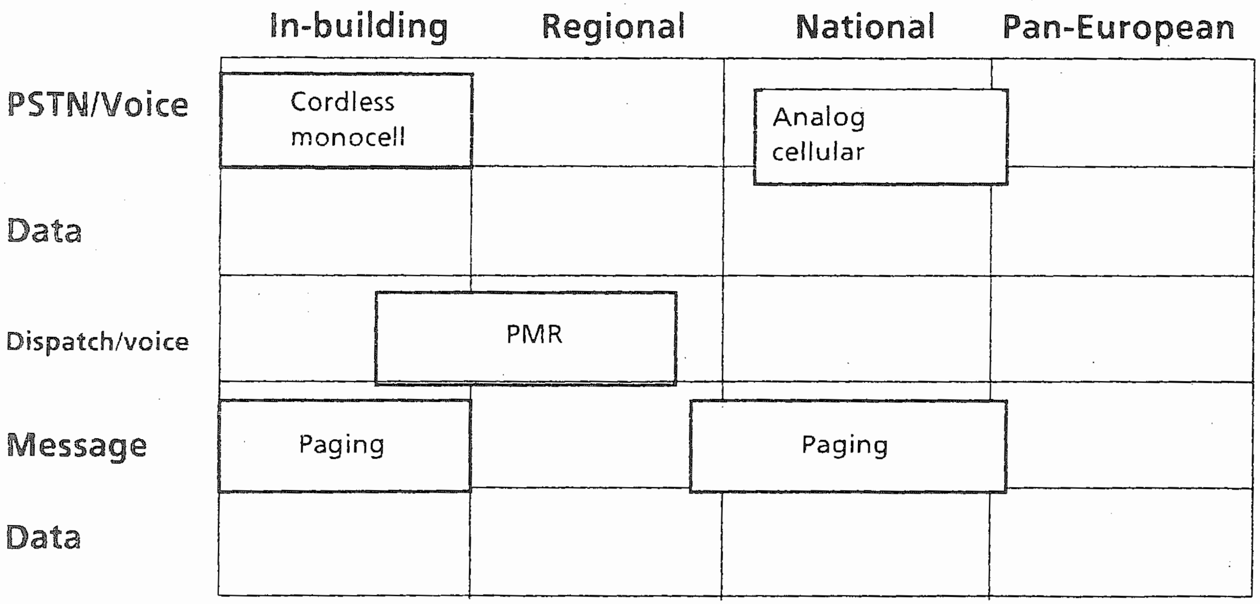

Figure 11.5 Information content/geographic-area segment covered by mobile-communication-systems available in 1986 in Europe.

Belgium, Portugal, and Switzerland, had an operational system. However, since the various mobile cellular-telephone systems were based on eight different standards, only two "roaming zones" existed: zone one included the four Scandinavian countries, and zone two provided roaming services between Belgium, the Netherlands, and Luxembourg. While data transmission over analog cellular systems is, in principal, possible, inherent technical limitations allow for only low data rates, which consequently results in high service charges.

In contrast to cellular mobile telephony, private mobile-radio systems were operated on a nonpublic basis only. Hence, with the exception of mobile radio systems used by organizations such as public safety or utility companies, most PMR systems had a very limited coverage, and no access to the PSTN. Moreover, most of the smaller and medium-sized companies have to share radiofrequency channels. As a consequence hereof, all users of a system are able to overhear all transmitted messages, which disqualifies conventional PMRs as a mobile communications medium if confidentiality is required. Besides, virtually no European conventional PMR was used for data transfer.

With regard to paging systems, it should be stressed that attempts to create a single European paging standard date back as far as 1970, when the Eurosignal standard was issued by CEPT. But it was only supported by 3 of the 26 CEPT countries: Germany (1974), France (1975), and Switzerland (1986). Although third-generation paging systems based on the POCSAG signaling scheme were introduced in numerous European countries between 1981 and 1986, they all were incompatible for reasons outlined in Section 11.3.1. In addition to these outdoor systems, in-building mobile communication has been made possible by single-line monocell cordless telephones and paging systems.

Figure 11.6 illustrates the dynamic development of new and/or improved mobile-communication systems between 1989 and 1991 in Europe. At the heart of this evolutionary process has been a profound change in the regulatory environment.

As described in detail in Section 10.2, various initiatives by the Commission of the European Communities, as well as the U.K. Department of Trade and Industry, made it progressively difficult for European PTTs to retain their service monopolies. Most PTTs/regulators opted to permit competition only for the provision of mobile communication services. Consonant with the ongoing liberalization of mobile services, the PTTs demonstrated increased flexibility concerning the introduction of new systems. More importantly, however, the CEC accomplished the enforcement of Pan-European mobile communication standards and operating frequencies.

In this context, the introduction of Pan-European digital cellular-telephone systems in more than 17 CEPT countries appears to be of particular relevance. It will overcome the limited coverage of previous analog systems in that it enables the GSM network subscriber to utilize roaming service in all European countries. Since GSM is independent of the various analog cellular-telephone systems, there will be digital-mode terminals only, which in turn allows the GSM equipment to become lightweight

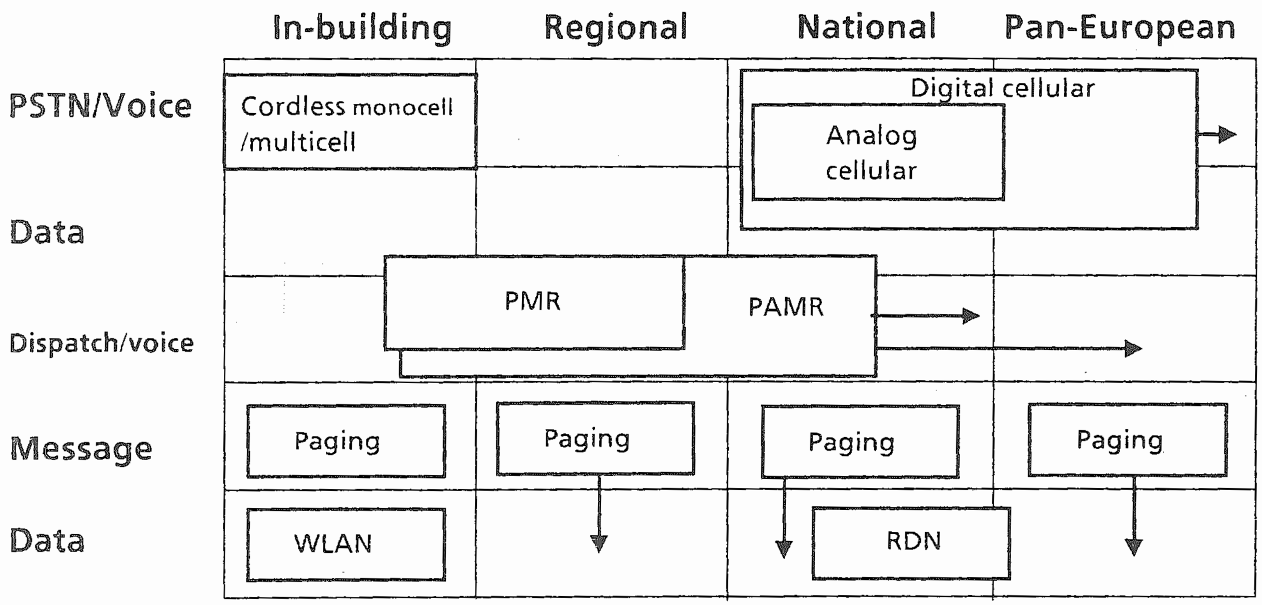

Figure 11.6 Information content/geographic area segments covered by mobile communications systems available or tested in 1991.

and low in battery consumption compared to the U.S. dual-mode equipment. It should be stressed that, aside from the basic telephone service, the GSM network also supports the transmission of messages, as well as data.

Similar to cellular telephony, the paging market is in the process of rapid change. Prior to 1991, there had been only one tone-only system that could be used in more than one European country. With Euromessage and, particularly, ERMES, two systems will provide tone-only, numeric, and alphanumeric paging services, on either a multinational or pan-European level. Like the GSM network, ERMES is based on a European standard, which was issued by ETSI.

Although there is no mandatory Pan-European standard for trunked mobile-radio systems, the mobile radio environment, too, is in a state of flux. As delineated in Figure 11.6, mobile radio systems are being installed by PTTs and other private organizations, which then offer public mobile-radio services on a commercial basis. These so-called public-access mobile-radio systems (PAMRs) are more spectrum efficient, provide significantly better service quality, and offer larger coverage than conventional PMRs. In addition, these systems are capable of supporting low to medium rate data transmissions. It should be noted, however, that not all European countries intend to provide nationwide coverage.

In addition to the introduction of systems with enhanced coverage and improved capabilities, entirely new networks are presently installed in some European countries. An example is radio data networks, which are public mobile-communications systems optimized for data transmission. With the help of these systems, it will be possible to support real-time dialog with the subscriber's host computer, as well as to send messages and fax to mobile terminals. Furthermore, various new systems are addressing the indoor environment. As depicted in Figure 11.6, WPBXs and WLANs will make it feasible to provide voice and data services within large premises.

11.6.2 Intersystem Competition of Second-Generation Systems

A comparison of Figures 11.5 and 11.6 illustrates that a growing number of mobile communications segments are covered by more than one mobile communications system. As a consequence, potential subscribers are increasingly in a position to chose the system that serves their communications needs best. In addition, more competition is inserted in the European marketplace by the fact that the number of licensees, (i.e., network operators) also increased rapidly due to the ongoing service liberalization.

Regarding the voice communications segment, existing analog and digital GSM cellular networks have to be considered as two independent systems; the extent to which intersystem competition will occur, depends on the structure of the service market. If GSM and analog networks are operated by a PTT on a monopolistic basis, no intersystem competition exists. However, in countries with one or two analog cellular operators and at least two GSM licensees, intersystem competition may become significant, and will depend on factors such as perceived need for Pan-European roaming services, as well as other inherent system advantages, GSM-terminal prices relative to existing analog-terminal prices, and GSM service charges relative to analog usage charges. Intersystem competition could also arise between cellular telephone and public access mobile-radio systems. Especially in countries where PAMRs will have nationwide coverage and access to the PSTN network, they may represent a viable alternative to mobile cellular-telephone networks for business users who frequently have to maintain contact within a closed group, and only occasionally access the PSTN. In fact, PAMRs that can be directly interconnected to a customer's PBX are capable of low-speed data transmission, and furthermore have the advantage of a usage-neutral service-charge structure, as opposed to the time-based service charge structure of cellular telephone networks.

As illustrated in Table 11.15, there are a host of possible mobile-communications systems capable of sending and receiving data.

The degree to which intersystem competition will materialize depends not only on the supported transmission speed and coverage of the various networks, but also on the number of systems that are installed, as well as the number of competing licensees. In general, it can be said that the competitive intensity will be highest in countries such as Germany, France, and the United Kingdom, in which essentially all described systems are operated by at least two licensees.

Indeed, these countries will have five different mobile-communications networks (see Table 11.14) capable of providing two-way data exchange. It should be noted that in France, Germany, and the United Kingdom, licensees for the provision of regional and national trunked PAMR services are not identical. Moreover, operators of analog and digital cellular-telephone networks are competing with PAMR licensees. In contrast, virtually no intersystem competition exists in countries where either only very few systems are installed, or systems are operated by one or very few operators.

Table 11.15
Overview of Data-Handling Capabilities of Land-Mobile Communications Systems in Germany, France, and the United Kingdom

Network Type	*Coverage*	*Gross Data Rate (max)*	*Basis for Service Charge*
Analog cellular	National	< 2,400 bps	Time/minute
Digital cellular	Pan European	9,600 bps	Time/minute
Trunked PMR	Regional or national	2,400 bps	Fixed rate or trans. data
Radio data network	Regional or national	19,200 bps	Fixed rate or trans. data

NOTES

[1] "Analog Cellular Roaming," 12.
[2] See Section 10.2.
[3] British Telecom holds 60% of Cellnet, while Securicor controls the remaining 40%.
[4] Gillick, "The evolution of the policy and regulatory framework in the U.K.," 188. Note that in 1991 Racal-Vodafone demerged from Racal Electronic PLC and became a completely separate company - Vodafone PLC.
[5] Stevenson, "The European Market," 36.
[6] Albert, "U.K.'s Two-Tier Approach to Service," Ch. 5.
[7] Although the system employs frequency reuse, it does not perform handoffs between adjacent cells.
[8] See Section 10.2.2.3.
[9] "Second French mobile telephone network," 370.
[10] See Section 11.1.1.3.
[11] Note: Compagnie Generale des Eaux controls 40%, while other French companies hold 47%. The remaining 13% is divided among Racal (U.K., 4%), Bell South (U.S., 4%), Fabricom (Belgium, 4%), Magneti Marelli (Italy, 0.5%), and Bromley International (Netherlands, 0.5%). See: Moggridge, "France Gets Set for Launch of First Private Cellular Service," 4-5.
[12] Bravo, "How the cellular market is developing in France," Ch. 6.
[13] Newman, "France Telecom and SFR invite applications from service provider," 3.
[14] There are still a large number of precellular systems operating such as, inter alia, the Netz B in Austria, Netherlands, Luxembourg and Germany, which are not considered here.
[15] The traffic is actually carried by a Dutch mobile-switching-center based in Rotterdam.
[16] Movatel is a joint venture between Telcom Portugal, Telefonos de Lisboa e Porto (TLP), and Racal Telecom
[17] Computations of penetrations rates are based on absolute subscriber numbers stated in Table 11.4 (1990). Population figures for EC countries were derived from Table 10.1. Population figures for EFTA countries and Sweden are based on data published in European Mobile Communications Report Issue 49 (February 1991): 15.
[18] McCartney, "How competition is developing in global markets," Ch. 4.
[19] Note: The U.K. with its two-tier service provision structure is an exception. The in Table 11.6 stated price for terminal equipment in the U.K. is heavily subsidized by service provider, and is therefore not comparable to prices in other countries.
[20] For a very detailed account of the problematics of the two-tier structure see: Albert, "U.K.'s Two-Tier Approach to Service," Ch. 5.
[21] Pricing a new Product: Cellular Phones in the U.K., London Business School, quoted in: McCartney and Gostich, "How U.K. cellular networks operate," 6.
[22] Paetsch, "Mehr Service fuer weniger Geld," 36.
[23] Herein, the Pan-European digital-cellular-mobile communications systems will be referred to as GSM.
[24] Council Recommendation of June 25, 1987 on the coordinated introduction of public Pan-European cellular digital land-based mobile communications in the Community (87/371/EEC).

[25] Council Directive of June 25, 1987 on the frequency bands to reserved for the coordinated introduction of public Pan-European cellular digital land-based mobile communications in the Community (87/372).
[26] See Section 8.1.3.5.
[27] Interface between mobile station and base station.
[28] Pinches, ''GSM-Europe leads the way,'' 95.
[29] Commission of the European Communities, COM (90) 565 final, 9.
[30] Ibid. Note: The 161 Recommendations are categorized into 13 sets of recommendations covering: preamble, general, service aspects, network aspects, MS-BS interface and protocol, physical layer on the radio path, audio aspects, terminal adapters for mobile stations, BTS BSC and BSC/MSC interfaces, networking interworking, service interworking, equipment specification and type approval specification, network management. See: Balston, ''PAN-European cellular radio,'' 7.
[31] Ibid. Note: It is expected that Phase II is concluded by December 1991.
[32] See Section 5.4.1.
[33] See Section 5.4.1.2.
[34] See Section 5.3.2.
[35] Balston, ''PAN-European cellular radio,'' 11.
[36] Ibid.
[37] Ibid.
[38] Rolle, ''Mobilfunk sprengt die Grenzen,'' 20.
[39] See Section 5.6.2.
[40] Herein MSC(h) means the home MSC of the subscriber and MSC(v) any other MSC.
[41] Balston, ''PAN-European cellular radio,'' 9.
[42] Ibid.
[43] Setchell and Deighton, ''Mobile & Intelligent Networks,'' 494.
[44] See Section 5.6.2.
[45] Commission of the European Communities, COM (90) 565 final, 16.
[46] Ibid.
[47] Ballard and Verhulst, ''Digital Cellular Mobile System,'' 47.
[48] Pinches, ''GSM-Europe leads the way,'' 93.
[49] Ibid.
[50] Ibid.
[51] Ballard and Verhulst, ''Digital Cellular Mobile System,'' 46.
[52] Pinches, ''GSM-Europe leads the way,'' 93.
[53] Young, ''First GSM milestone passes quietly,'' 82.
[54] ''Zwischen Wunsch und Wirklichkeit,'' 38-40.
[55] ''Zwischen Wunsch und Wirklichkeit,'' 38-40. Note: The private German GSM operator therefore plans to subsidize mobile GSM stations in order to overcome potential reservations on part of potential subscribers.
[56] Note: Nevertheless, there are various privately-owned and operated PMRs, which are indeed large and complex. Examples, therefore, are PMRs employed for public safety and public utility companies.
[57] Hardiman, ''The role of private mobile radio,'' Ch. 17.
[58] Green, ''The mobile explosion,'' 17.

[59] Moggridge, "DTI to advertise new licences," 1.
[60] These five are: National Mobile Radio, Relcom Communications, Sinclair Communications, Air Call, and ECT.
[61] The two national service providers are Band Three Radio and National One.
[62] Moggridge, "DTI to advertise new licences," 1.
[63] Air Call returned its license to the DTI.
[64] In May 1989 the DTI revoked the license of ECT.
[65] These companies are: National Mobile Radio, Relcom Communications, and Sinclair Communications.
[66] Moggridge, "DTI takes tough line on slow-starting PMR companies," 2.
[67] Rowlatt, "New common base station licences," 8.
[68] Ibid.
[69] Ibid.
[70] Ibid.
[71] Ibid., 9.
[72] "Schlacht um neue Lizenzen," 55.
[73] These companies are: DBF Bundelfunk, Preussag, Regiocall, Primus, RegioKom, Sprintel, Rheinelektra, Thuringer Mobilfunk, Quickfunk.
[74] Mullins, "Germany set to choose first private operators," 8.
[75] Rowlatt and Newman, "France awards first trunked private mobile radio licenses," 6.
[76] Ibid.
Note: The six licenses were awarded to: Lyonnaise des Eaux (Lyonnaise des Eaux 39%, Motorola 39%, Dicomabe 10%, Credit Agricole 12%), Serep, Matra (Matra Comm 51%, Millicom 34%, GTME 15%), M. Laudren & Cie, ETDE (ETDE 80%, TRT 20%), France Telecom.
[77] Rowlatt and Newman, "France awards first trunked private mobile radio licenses," 6.
[78] Ibid.
[79] Mullins, "French Government awards 15 new trunked public PMR licenses," 2.
[80] Mullins, "Germany set to choose first private operators," 8.
[81] Ibid.
[82] Ibid.
[83] Newman, "Portugal prepares tenders," 2.
[84] Mullins, "Germany set to choose first private operators," 8.
[85] Ibid.
[86] Examples of non-private users are public utility companies, public services, large corporations, etc.
[87] McKenzie, "MPT in Europe," 148.
[88] Ibid., 149.
[89] A detailed description of the workings of ALOHA signaling system is given in: McKenzie, "MPT in Europe," 148-154.
[90] Rowlatt and Newman, "France awards first trunked private mobile radio licenses," 6. Striebel, "Why Germany needs trunked PMR," 20-25.
[91] Ibid., 22.
[92] See Section 10.2.5.

[93] These two systems are Mobitex (jointly developed 1986 by Ericsson/Sweden PTT) and a proprietary system developed by Motorola.
[94] "Mobile Data Developments in Europe and the US." 8.
[95] Nabarro, "ERMES," 42.
[96] Rowlatt, "Euromessage," 37.
[97] Ibid.
[98] Blanc, "Mobile Telecommunications Policy," 9.
[99] Ibid.
[100] Silberhorn, "Standards-The priorities for mobile communications in the 90s," Ch. 10.
[101] "ERMES takes wing as PTTs sing MoU on paging," 6.
[102] Ibid.
[103] Nabarro, "ERMES," 41-42.
[104] Ibid., 44.
[105] Ibid.
[106] See also Paetsch, "PCN/CT2," 44.
[107] Nabarro, "ERMES," 44..
[108] Gusbeth, Mobilfunk Lexikon, 41.
[109] See Section 8.5.2.
[110] While 150,000 CEPT CT1 phones were sold in Germany by the end of 1989, it was assumed that between 100,000 and 200,000 illegal units are also in use.
[111] Tuttlebee, "Cordless Telecommunications," 60.
[112] Common air interface specification, 1.
[113] ADPCM is also used for wired telephones according to CCITT Recommendation G721, 1988. See Section 5.4.1.2.
[114] Gardiner, "Second generation cordless," 77.
[115] Commission of the European Communities, Council Recommendation on the Coordinated Introduction of DECT, 10.
[116] Ibid.
[117] Since DECT CTs are working behind PBXs, major PBX vendors are interested in keeping the defined set of features as small as possible, while non-PBX manufacturer would prefer a fully defined CI so that all PBX features may be supported, thus reducing the scope of PBX producers to differentiate themselves.
[118] Tuttlebee, "Cordless Telecommunications," 60.
[119] Note: The frequency is adaptable within the 1-3 GHz frequency band.
[120] Commission of the European Communities, Council Recommendation on the Coordinated Introduction of DECT, 10.
[121] Ibid.
[122] Blanc, "Mobile Telecommunications Policy-EC View," Ch. 9.
[123] Commission of the European Communities, Council Recommendation on the Coordinated Introduction of DECT, 6.
[124] Newman, "Commission moves swiftly," 2.
[125] Newman, "Cordless fiasco," 1, 4.
[126] Newman, "CT-2 Plus," 3.
Note: CT2 Plus is currently supported by Motorola, Northern Telecom and GPT.
[127] Ibid, 4.

[128] Ibid.
[129] Ibid.
Lipman, Wang and Spencer, Comments of GEC Plessey Telecommunications Ltd., 29.
[130] Olivetti is currently the only company that announced a cordless LAN on basis of DECT.
[131] In July 1992, Northern Telecom announced its first small WPBX, ''Companion'' (based on CT2). Siemens became the first manufacturer to launch a small wireless system, ''Gigaset'' (based on DECT).
[132] ''ETSI eyes new PMR specs,'' 6.
[133] Ibid.
[134] Ibid.
[135] ''Motorola Altair in Germany and Spain,'' 7.