4. Data Services

4.1 Introduction

This section describes the data services supported by PCI.

Four different data services are supported over the 32 kbit/s B channel:

(1) full-duplex asynchronous data services
(2) transparent data services
(3) X.25 packet data services
(4) Group III (G3) Fax services

The asynchronous data service allows subscribers to access landline computer facilities with asynchronous data rates of 300 to 19200 bit/s (300, 1200, 2400, 4800, 9600, 14400 and 19200 bit/s). It also allows landline subscribers to access portable terminals with the same asynchronous rates. Asynchronous data employs an Automatic-Repeat Request (ARQ) protocol for the retransmission of errored blocks , together with a Forward Error Correction (FEC) scheme. A flow control mechanism is used to control the data rate at the user terminal or the host computer when severe degradation of radio transmission occurs for a long period of time.

The transparent data service provides the user with unrestricted access to the 32 kbit/s B channel, or to subrate channels. Data rates are synchronous and user selectable. The supported rates are: 300, 1200, 2400, 4800, 9600, 14400, 19200 and 32,000 bit/s. The service has the capability of providing FEC for all rates except 32 kbit/s, at the user's request. Reed Solomon (RS) codes are used for FEC similar to the asynchronous data service. However, there is no ARQ protocol and there is no guarantee of data integrity.

The X.25 packet data service supports the use of X.25 terminals over the system. X.25 terminals may be connected to a data terminal and send/receive data over a public or private landline packet data network.

The G3 Fax service allows G3 Fax machines to be connected to a PCI data terminal, and send/receive fax messages over (a) a public or private landline packet data network that supports a FaxPad (see section 4.5 for more discussion), or (b) through a circuit switched connection.

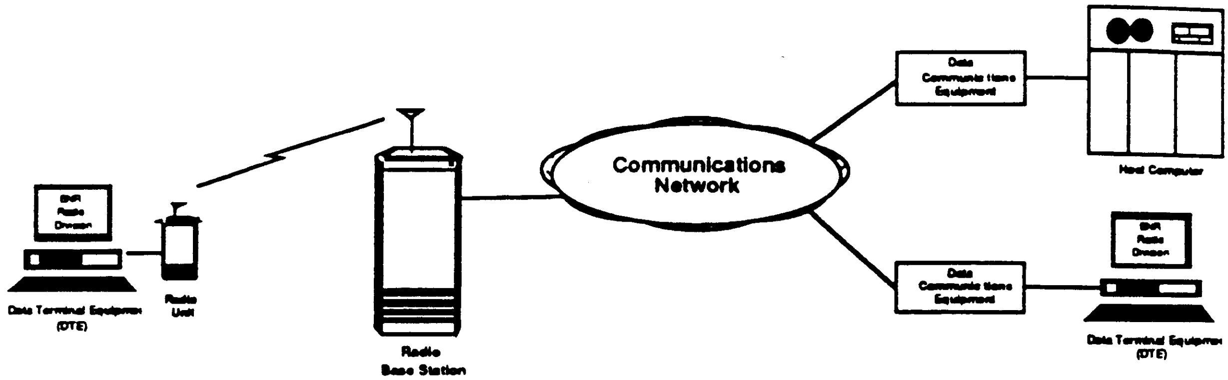
4.2 Asynchronous Data Transport

4.2.1 General System Configuration

Fig. 4.1 shows the general system configuration of the asynchronous data service. A subscriber may connect a Personal Computer (PC) or a Data Terminal Equipment (DTE) directly to the portable data terminal through an RS-232 interface. The data terminal runs the asynchronous data firmware that is responsible for the transport of data over the radio link. The corresponding asynchronous data software runs at the Base station and Network Controller. After appropriate conversion, the data is transmitted through the network to a Data Communications Equipment (DCE) device which is connected to a host computer, a workstation, or any other device that appropriately interfaces to it.

In effect two protocols exist: one for the radio link and one for the landline link, with appropriate protocol conversion taking place at the Radio Base station.

Figure 4.1
General system configuration for asynchronous data service



4.2.2 System Description

Fig. 4.2 shows the main components of the system that enable the asynchronous data service which are:

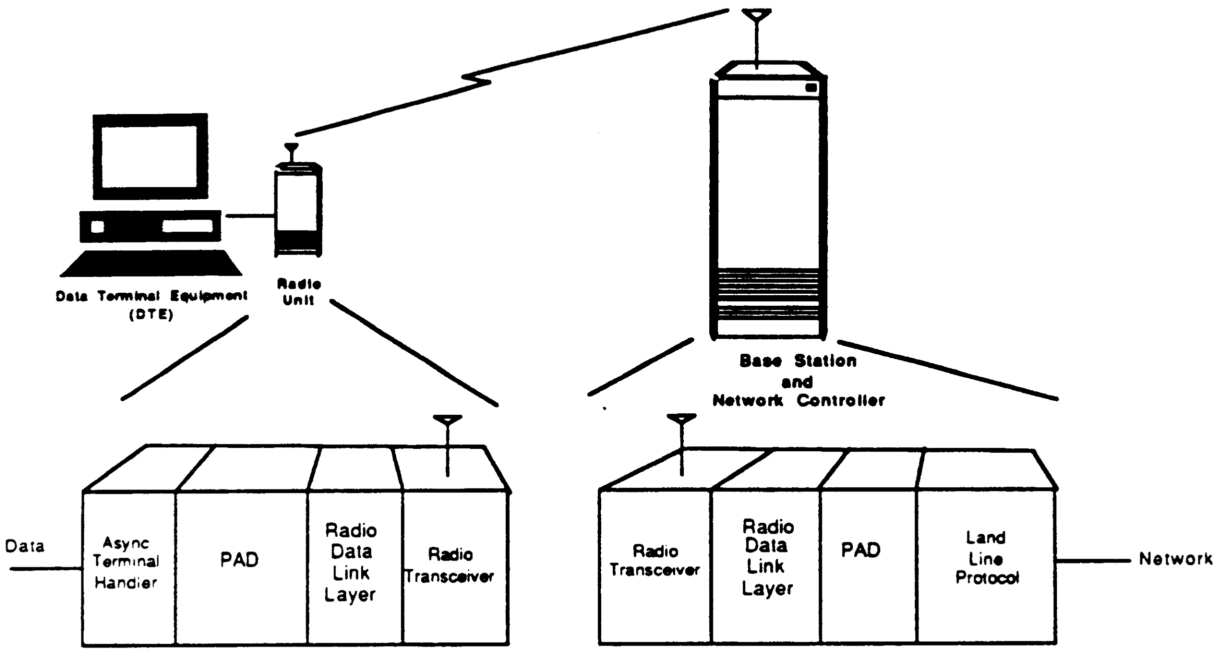
- PAD - Packet Assembler/Disassembler
- RDLL - Radio Data Link Layer
- LPL - Land-Line Physical Layer.

The PAD provides for the asynchronous to synchronous interface between the asynchronous PC or DTE to the synchronous radio data link. The RDLL implements Forward Error Correction (FEC)[2] together with an Automatic Repeat Request (ARQ) protocol[3]. The LPL provides access to a variety of computer facilities. The PAD and RDLL reside in both the PCI data terminal and the Base station and Network Controller, whereas the LPL resides only at the Base station and Network Controller side. The asynchronous terminal handler provides the RS-232 interface to the PC or DTE.

[2] S. Lin and D. Costello, "Error Control Coding: Fundamentals and Applications," Prentice-Hall, April 1983.

[3] S. Lin, D.J. Costello, M.J. Miller, "Automatic-Repeat Request Error-Control Schemes", IEEE Communications Magazine, Vol. 22, No. 12, pp. 5-17, December 1984.

Figure 4.2 System description



4.2.2.1 Land-Line Physical Layer (LPL)

The LPL provides access to land-line computer facilities. It may be one of the existing asynchronous standards such as voiceband modems or rate adaption protocols. By conforming to widely used standards, there is no need to use specialized network termination equipment for users accessing land-line computer facilities from a portable data terminal.

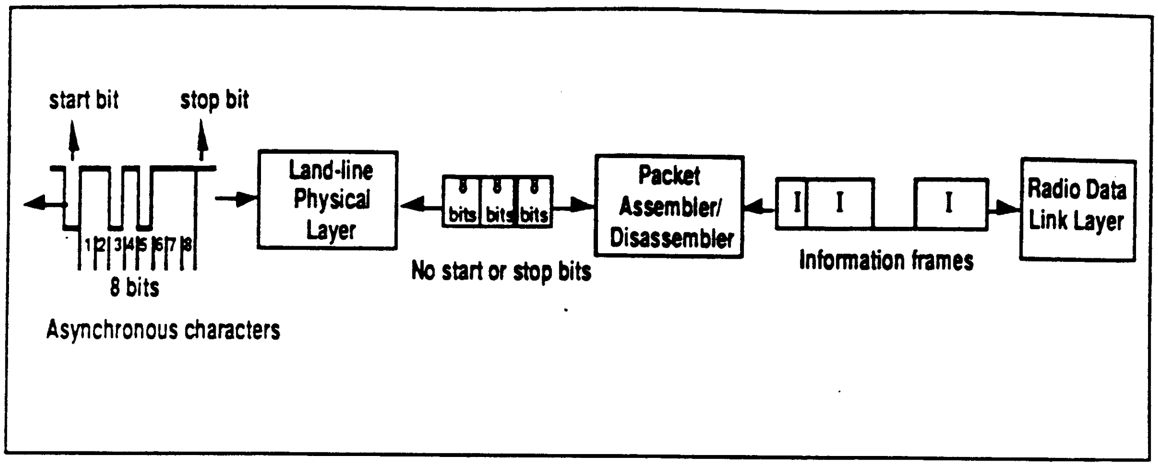
Examples of LPLs may be:

- V.32 modem (9600/4800 bit/s)
- V.22 bis modem (2400/1200 bit/s)
- V.21 modem (300 bit/s)
- Bell 212A modem (1200/300 bit/s)
- Rate adaption protocols (e.g. V.120)
- Others for further study (e.g. MNP for some modems)

4.2.2.2 Packet Assembler/Disassembler (PAD)

The Packet assembler/disassembler lies between the LPL and the RDLL (in the Base Station and Network Controller case). In the forward direction the LPL receives asynchronous characters from the land-line. Asynchronous characters typically consist of a start bit that indicates the start of a character, one or more stop bits that indicate the end of the character, and a certain number of bits in between that define the specific character. The characters may also contain a parity bit . The LPL strips these asynchronous characters from their start, stop and parity bits and provides the PAD with the remaining bits. An example is shown in Fig. 4.3 for the case of 1 start, eight data bits, 1 stop, no parity. The PAD assembles the asynchronous characters into information frames that are passed on to the RDLL for transmission over the synchronous radio link.

Figure 4.3 Packet Assembler/Disassembler



In the reverse direction the PAD receives information frames from the RDLL, disassembles them into characters, and passes them to the LPL.
The PAD also provides for an XON-XOFF flow control mechanism in order to prevent buffer overflow when radio transmission degrades for a long period of time. The PAD generated flow control does not interfere with terminal or user generated flow control. The PAD buffers should be made sufficiently long to avoid overflow due to transmission delays and DTE response times.

At the portable data terminal side, the PAD performs the exact same functions, with the exception that it receives/sends asynchronous characters to a terminal handler instead of the LPL.

4.2.2.3 Radio Data Link Layer

The RDLL is responsible for the transport of data over the radio link. It must overcome the transmission impairments presented by the mobile radio channel. The radio data link layer uses a Type I Hybrid Automatic Repeat Request (ARQ) scheme. This scheme combines Forward Error Correction (FEC) with an ARQ protocol.

If an ARQ protocol is used alone then, because of the severity of the radio channel, the throughput would degrade rapidly with increasing bit error rate. The application of FEC coding reduces the probability of an ARQ frame error, and thus limits the number of retransmissions which in effect increases the throughput.

4.2.2.3.1 Forward Error Correction

Reed-Solomon (RS) block codes are used for FEC. RS codes have proved to be very powerful and efficient codes for use in the mobile radio channel environment [4]. Some of the advantages that RS codes offer are:

- sufficient flexibility to support various coding rates with no program redesign. This will be required for the support of different land-line access rates (see section 4.2.2.3.3).
- the coding rate can be optimized for each different land-line access rate.
- the codes can support simultaneous correction and detection. This eliminates the need for using a cyclic redundancy check (CRC) at the ARQ level. Greater detection capability than with a CRC-16 is possible, and more parity symbols can be provided by eliminating the CRC.
- low computational complexity

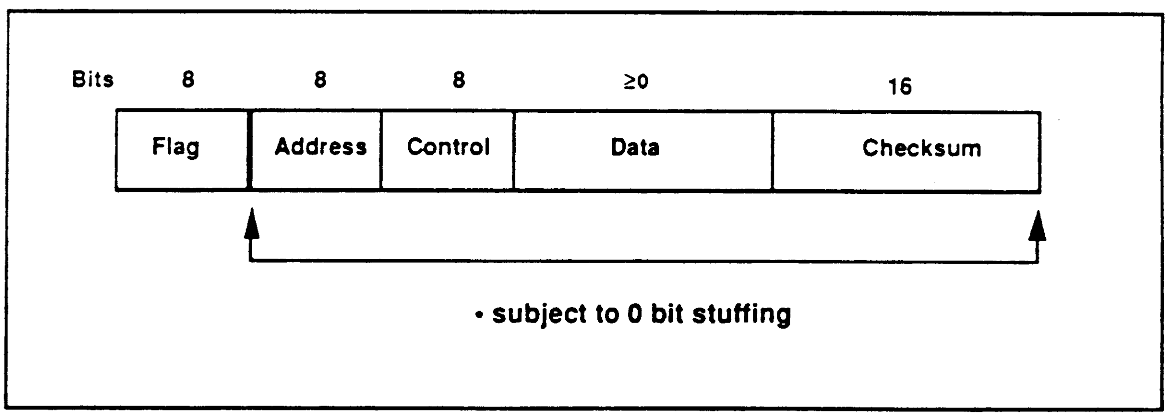
An RS code is described as a (n,k,d) code in this context, where k is the number of data symbols, n-k is the number of parity symbols and d is the number of parity symbols (out of the n-k parity symbols) reserved for error detection.

4.2.2.3.2 Automatic Repeat Request Protocol

The ARQ protocol used is one derived from the High-Level Data Link Control (HDLC) family[5]. The protocol is a modified version of the Link Access Procedure Balanced protocol (LAPB).

LAPB is a bit oriented data link layer protocol which uses zero bit stuffing to preserve the uniqueness of flag bytes, which are used to indicate the start of each LAPB frame. A LAPB frame is shown in Fig. 4.4.

Figure 4.4 LAPB frame



[4] G. Mony, B. Toplis, J. Michaelides, Performance Assessment of Data Transport Alternatives for Digital Cellular Radio , IEEE Vehicular Technology Conference, pp. 336-340 , 1990.

[5] International Standards Organization. "Data communication - High-Level data link control procedures - Consolidation of elements procedures," Ref. No. ISO 4335-1983(E)

The flag byte is at the beginning of each frame, and is used to indicate the start of the frame. The address byte is used to distinguish commands from responses (for point-to-point lines). The control byte is used primarily for sequence numbers and to distinguish the different types of frames. The information field is used for arbitrary information and may be arbitrarily long (length is actually limited by the effectiveness of the Cyclic Redundancy Check (CRC)). The CRC bytes are used for frame error detection.

4.2.2.3.2.1 Modified LAPB

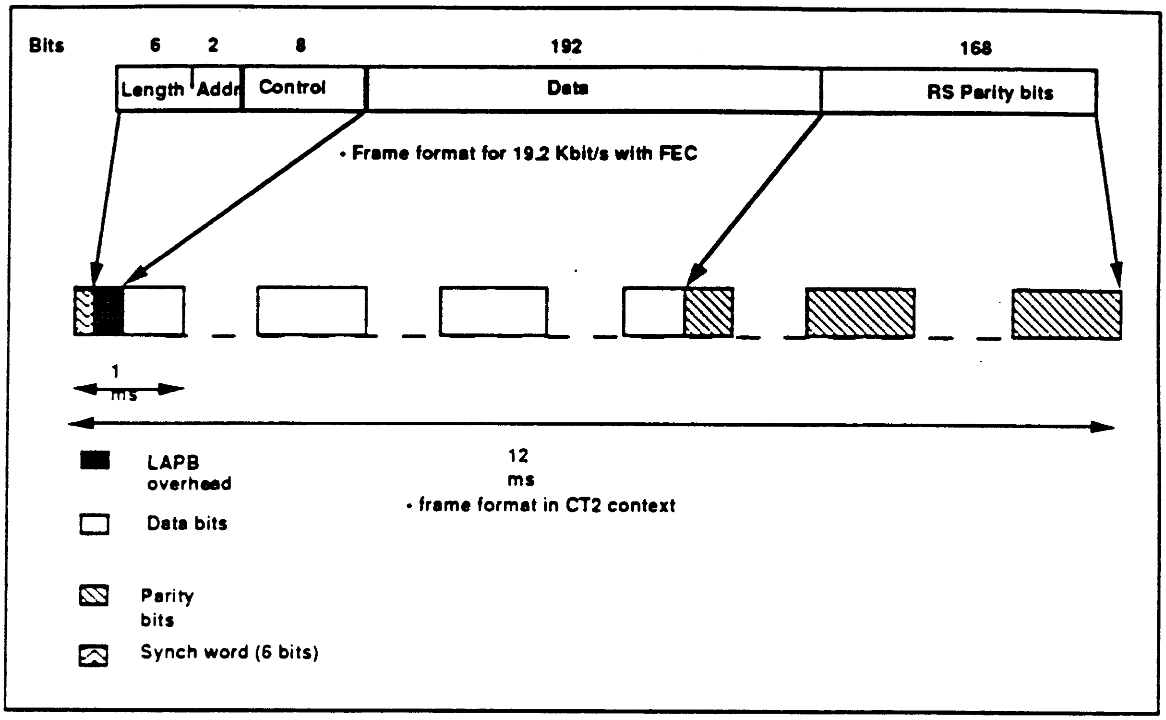
The LAPB frame is to be inserted in a number of transmit bursts. A synchronization word (6 bits) is used at the beginning of the frame to establish which burst is first in the frame. Thus, by sharing PCI framing, the LAPB flag bytes and zero bit stuffing can be eliminated. The ARQ frame length information must be added to the frame header, which can be multiplexed into the address byte of LAPB. The length information is six bits long, which is sufficient to cover the maximum length of data in a LAPB frame. The elimination of the flag bytes and zero bit stuffing results in an increased number of available bits that are used by the FEC code. The data field is a multiple of 8, since it will contain a certain number of eight bit characters. When there is not enough data to fill the maximum data field available, then arbitrary information is used for filling. The CRC bytes are also eliminated, since RS codes already provide for error detection capability. The resulting frame is shown in Fig. 4.5, where I is the number of eight-bit characters to be transmitted.

Figure 4.5 Modified LAPB frame

Bits	6	2	8	8*I
	Length	Addr	Control	Data

The modified LAPB frame is aligned with the Multiplex 1 burst structure (CAIS, part 2, Figure 2.2). Multiplex 1 supports 64 B channel bits. Six bursts are used to carry a complete LAPB frame plus the FEC parity bits (see Fig. 4.6).

Figure 4.6 Frame Format in PCI Context



In order to provide the maximum desired throughput of 19.2 kbit/s, we need at least 192 bits out of the 384 bits provided by six transmit bursts. The PAD strips the start, stop and parity bits so the asynchronous rate of 19.2 kbit/s translates to a 15.36 kbit/s synchronous rate over the air interface (19.2 * 8/10= 15.36). This corresponds to 184.32 bits for a 12 ms frame. However, since we restrict the LAPB data field to be a multiple of 8 we actually need 192 bits. Adding the bits required by the length+address and control bytes we get:

$$192+8+8 = 208 \text{ bits}$$

If we use an RS code with 6 bits per symbol, then the maximum block length we can use is 63 symbols or 378 bits. The resulting RS code is (378/6,208/6)=(63,35;1) with 1 parity symbol reserved for error detection. Also, the LAPB timeouts have to be customized for the PCI network implementation.

4.2.2.3.3 Multimode FEC

In the case of the lower rates (eg. 9600 bit/s, 4800 bit/s etc.) it is advantageous to use a different more powerful FEC code, that would utilize the extra available capacity. This would provide better error protection and consequently it would improve the throughput. Experimental results of using this method have been demonstrated for 9600 bit/s[6].

Therefore, a multimode FEC technique is used, where the FEC code used is determined by the maximum bit rate provided by the user. Table 4.1 lists the resulting RS codes.

Table 4.1 Multimode FEC

Mode	Rate (bit/s)	RS code (n,k;d)
1	300	(63,4;1)
2	1200	(63,6;1)
3	2400	(63,7;1)
4	4800	(63,11;1)
5	9600	(63,19;1)
6	14400	(63,27;1)
7	19200	(63,35;1)

4.3 Transparent Data Service

The transparent data service provides the user with an unrestricted access to the 32 kbit/s B channel, or to subrate channels. Data rates are synchronous and user selectable. The supported rates are: 300, 1200, 2400, 4800, 9600, 14400, 19200 and 32,000 bit/s. The service has the capability of providing FEC for all rates except 32 kbit/s, at the user's request. Reed Solomon (RS) codes are used for FEC similar to the asynchronous data service. However, there is no ARQ protocol, and there is no guarantee of data integrity.

4.4 X.25 Packet Data Service

This service allows terminals with X.25[7] capabilities to communicate with private or public landline packet data networks (Fig. 4.7).

In Fig. 4.7, the X.25 layer 2 at the portable data terminal communicates with the X.25 layer 2 of the X.25 terminal. The data is then given to the RDLL for transmission over the radio link. At the Base station and Network controller, the RDLL (a) passes the data to an X.25 layer 2 for transmission over a landline packet data network or (b) distributes the data locally. In the

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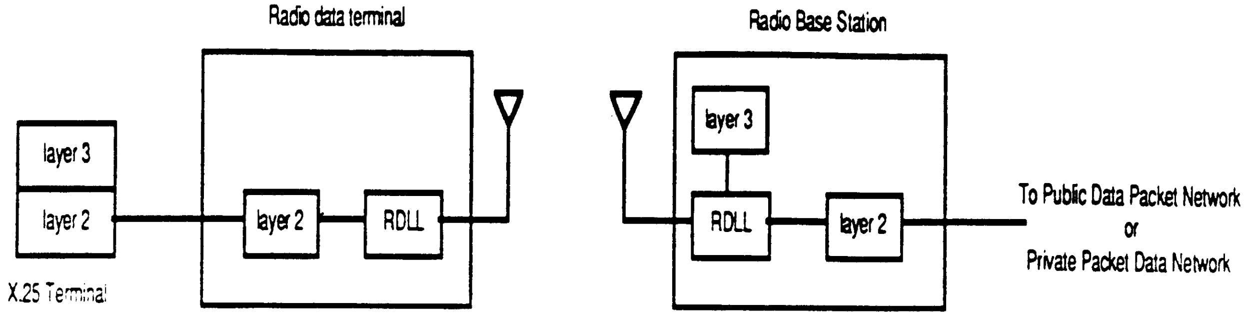
6 G. Mony, J. Michaelides, B. Toplis, Asynchronous Data Transport on Digital Cellular Radio, Worldwide Personal Communications Comforum, June 1990.

7 The International Telegraph and Telephone Consultive Committee. "Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit, " Recommendation X.25, Malaga-Torremolinos, 1984

second case, an X.25 layer 3 is implemented at the Base station and Network Controller for communicating with the X.25 terminal's layer 3.

Figure 4.7 X.25 Packet Data Service



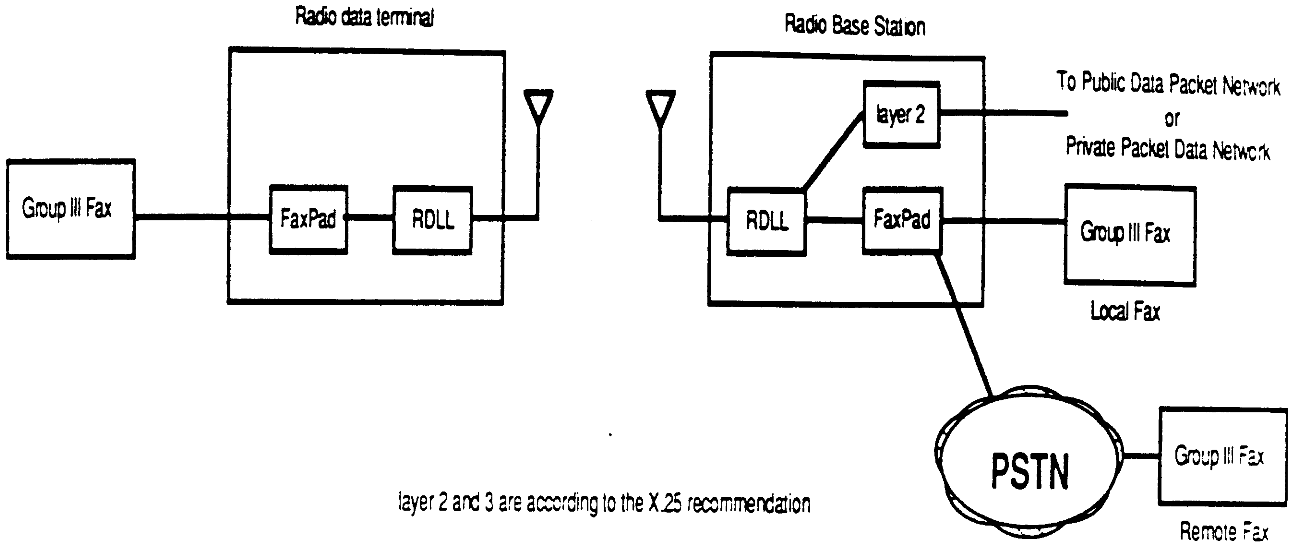
layer 2 and 3 are according to the X.25 recommendation

An asynchronous terminal can also communicate over a landline packet data network by accessing a PAD using the asynchronous data capability of the PCI system, as described in section 4.2.

4.5 Group III Fax Service

The PCI system supports the transmission and reception of G3 Fax messages. A G3 Fax machine is connected to the PCI data terminal via an analog or digital interface (Fig. 4.8). A FaxPad is used as an interface between the fax protocol and the radio transport. The FaxPad provides for appropriate mechanisms in order to communicate with a G3 Fax machine and to receive the user data. It also provides for the exchange of control information between FaxPads. It assembles/disassembles the user data and control information into/from packets, using datafields defined in the X.25 recommendation (packet level). The FaxPad uses the RDLL as its layer 2.

Figure 4.8   G3 Fax Service



A G3 Fax machine connected to a PCI data terminal may access a G3 Fax machine (a) over a landline packet data network or (b) through a circuit switched connection. In the first case, the FaxPad located at the PCI data terminal communicates with a corresponding Faxpad located within the landline packet data network. This case allows G3 Fax machines connected to PCI data terminals to access G3 Fax machines that use a packet data network to transmit or receive their messages. In the second case, the FaxPad located at the PCI data terminal communicates with the FaxPad located at the Base station and Network controller for a circuit switched connection to a local G3 Fax machine, or to a G3 Fax machine connected to the Public Switched Telephone Network (PSTN).

In case the FaxPad is implemented within the G3 Fax machine, then this Fax machine may use the X.25 packet data service (as described in section 4.4) for the transmission/reception of Fax messages.

Currently, the CCITT is in the process of examining recommendations X.5, X.38 and X.39, which specify a FaxPad that would provide connection of G3 Fax machines through packet data networks. These recommendations could be used for the implementation of the FaxPad shown in Fig. 4.8.

The RDLL is the same as specified for the asynchronous data service.

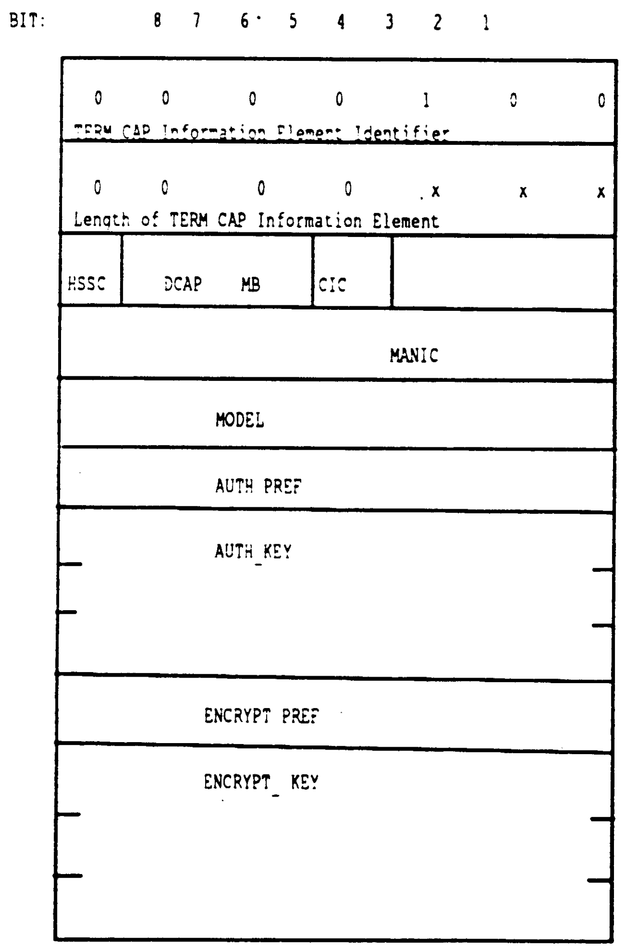
5. Security

Cryptographic techniques can provide both privacy and authentication. Annex C of the CT2 CAIS specifies the mechanisms of basic authentication to be used in PCI handsets.

5.1 Layer 3 Information Elements

5.1.1 Terminal Capabilities Information Element

Encryption for calls is offered as an option in the PCI system. The option is invoked via the Terminal Capabilities Information Element (TERM_CAP). This information element is described in the CAIS Signalling Layer 3, Section 2.2.10. Additional fields are added to the Terminal Capabilities Information Element to support encryption.



Encrypt_Pref is used by the CPP to indicate to a CFP which of the encryption algorithms offered by the CPP is the CPP's preferred algorithm. If only one algorithm is offered, this must be indicated as the preferred algorithm in this field.

Encrypt_Key is a bit field used to indicate to a CFP which encryption algorithms the CPP is capable of performing. A bit if set to 1 indicates that the CPP is capable of performing the associated algorithm, and if the bit is set to 0 the CPP is not capable of performing the associated algorithm.

5.1.2 Alternative Encryption Request Information Element (ENCRYPT2_REQ).

This alternative encryption request information element is used by a CFP to initiate the alternative call encryption process.

BIT: 8	7	6	5	4	3	2	1
0	x	x	x	x	x	x	x
ENCRYPT2 REQ Information Element Identifier							
Length of ENCRYPT2 REQ Information Element							
ENCRYPT NO							

ENCRYPT_NO is used to indicate to the CPP which (if any) of the encryption algorithms offered by the CPP is to be used.

5.2 Mutual Authentication & Encryption Key Generation

The voice/data channel (B channel) is encrypted using a private key cryptosystem. The private key cryptosystem could be based on the encryption function "F" used for Telepoint authentication. Two private keys are used (one for each direction of transmission). The private keys are derived by extending the telepoint authentication procedure (CAIS, Annex C). A new pair of encryption keys is generated for each session or call.

A handset contains identification information which is transmitted to the CFP during the setup and authentication phases of a call. This information is sufficient to uniquely identify the handset. The handset also stores internally a PIN number which is transmitted to the base station during the setup and authentication phases of a call.

To avoid problems of fraud (arising from the monitoring of the air-interface and the cloning of valid handsets) the PIN is encrypted before transmission over the air-interface.

The process by which the content of the PIN field is interrogated by the base and the handset authenticated is:

-The base transmits to the handset a 32-bit random challenge (RAND1) in the Layer 3 Information Element AUTH_REQ where it is received as RAND1'.

-The handset encrypts the 64-bit PIN using an encryption function "F", and using RAND1' as the key to produce the the 32-bit cyphered-PIN (CPIN1).

-The handset then transmits CPIN1 to the base in Layer 3 Information Element AUTH_RES where it is received as CPIN1'.

-The base determines the expected-PIN (E-PIN1) for the handset using the Identification Information and using the same function "F", with RAND1 as the key, calculates the expected value of CPIN1 (E-PIN1).

-The base compares the received CPIN1 (CPIN1') with the expected value (E-PIN1). If the values match the handset is judged to be valid.

A similar process can be used to authenticate the base to the handset:

-The handset transmits to the base a 32-bit random challenge (RAND2) in the Layer 3 Information Element AUTH_REQ where it is received as RAND2'.

-The base encrypts the 64-bit PIN using an encryption function "F", and using RAND2' as the key to produce the the 32-bit cyphered-PIN (CPIN2).

-The base then transmits CPIN2 to the handset in Layer 3 Information Element AUTH_RES where it is received as CPIN2'.

-The handset encrypts the 64-bit PIN using the same function "F", with RAND2 as the key, calculates the expected value of CPIN2 (E-PIN2).

-The handset compares the received CPIN2 (CPIN2') with the expected value (E-PIN2). If the values match the base is judged to be valid.

The process by which the encryption key (Key_P_to_F) for the CPP to CFP link is obtained is:

-the handset and base each encrypt the 64-bit PIN using the encryption function "F" and using CPIN1 as the key to produce the 32-bit cyphered CPIN1 (C-CPIN1).

Key_P_to_F = C-CPIN1.

The process by which the encryption key (Key_F_to_P) for the CFP to CPP link is obtained is:

-the handset and the base each encrypt the 64-bit PIN using the encryption function "F" and using CPIN2 as the key to produce the 32-bit cyphered CPIN (C-CPIN2).

Key_F_to_P = C-CPIN2.

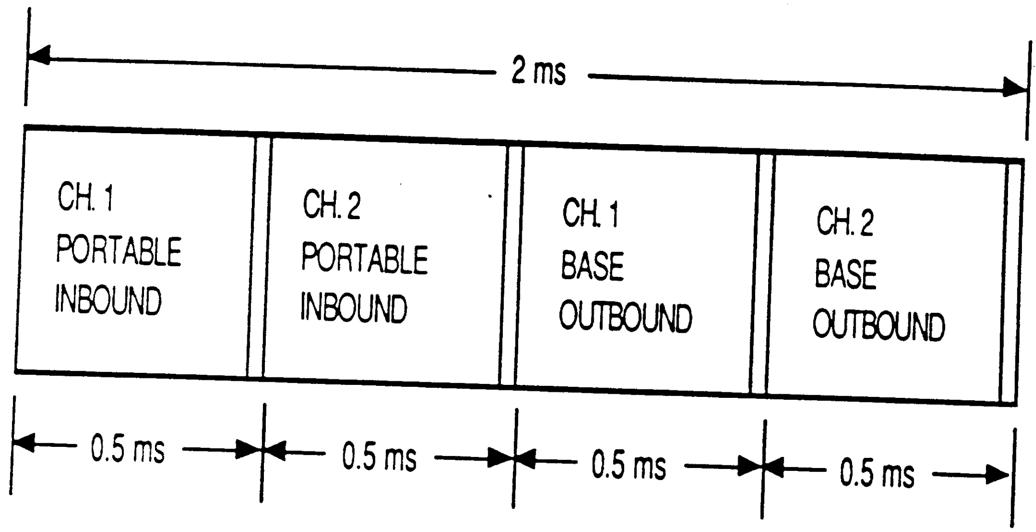
The method can be easily generalized to generate 64-bit keys if required.

The sections above have assumed that the base station, given the identity of the handset (and account), will know the value of the PIN expected from the handset (E-PIN).

6. Half-Slot Channels

The provision for half-slot channels will allow PCI to take advantage of future low bit rate speech coders and/or more efficient modulation schemes. A number of different frame structures are possible. One option, presented in Fig. 6.1, would allow the use of 2-channel TDMA on each standard 2 ms frame. Radios using the half-slots would still have to meet the channel spectral mask and power levels; thus, they would cause no more interference than standard full-slot transmitters.

Figure 6.1: Frame Structure for Half-Slot Channels



Application of BNR Inc.
For Experimental License
Exhibit 1

1. General Description of Experiments

BNR Inc. ("BNR"), the research subsidiary of Northern Telecom Inc. ("Northern Telecom"), requests grant of an experimental radio license to gain experience with personal communications systems and develop concepts of Northern Telecom's personal communications services ("PCS") vision. This vision has described to the Commission in Northern Telecom's comments in Docket 90-314, the Notice of Inquiry related to PCS. A copy of Northern Telecom's filing is attached as Appendix A.

Key to Northern Telecom's PCS vision is the recognition of the need for near-term solutions while working towards the resolution of long term issues. This is both to allow equipment manufacturers and service providers the opportunity to gain experience with this technology, and also to satisfy an existing consumer market demand for PCS. The technology proposed by Northern Telecom as a standard for low power PCS is Personal Communications Interface ("PCI"). This technology is an enhancement of CT2, adapted to the North American market. The technical specification of the PCI protocols is contained in an Annex to the Northern Telecom's PCS comments in Appendix A hereto.

BNR plans to conduct technical tests in the 864-868 MHz and 930-960 MHz bands to assist in the development of the PCI concept. Experiments will use equipment and technology based on the CT2 standard and the proposed PCI protocols. These laboratory tests will be conducted in several BNR and Northern Telecom sites and their surrounding areas, as specified below.

BNR also requests permission to conduct technical and market research tests using CDMA/spread spectrum technology using the Part 15 901-929 MHz ISM bands, the 1850-1990 MHz band, the 2400-2483.5 MHz band, and the 5725-5850 MHz band. The granting of this license will allow BNR to evaluate CDMA technology in a variety of controlled environments and applications. The proposed experiments will provide BNR with valuable data on PCI and PCS capabilities. A description of the proposed CDMA/spread spectrum experiments is included in Section 4 of this exhibit.

Equipment used in conducting these tests will be primarily developed by BNR in conjunction with Northern Telecom. BNR will also use some other manufacturers' equipment for measurements and evaluations. BNR will coordinate its use of the spectrum with existing users of the spectrum and other experimental license operators in the area.

2. <u>Particulars of Operation</u>

BNR provides the following information on the particulars of operation as per Item 4 of the application.

Frequency	Power (C)	Emission (E)	Modulating Signal	Necessary Bandwidth (kHz)
864-868 MHz	10 mW		Audio	100 kHz/Channel
930-960 MHz	10 mW		Audio	100 KHz/Channel
902-928 MHz	1 watt	*	Voice/Data	2 MHz/Channel*
1850-1990 MHz	1 watt	*	Voice/Data	2 MHz/Channel*
2400-2483.5 MHz	1 watt	*	Voice/Data	2 MHz/Channel*
5725-5850 MHz	1 watt	*	Voice/Data	2 MHz/Channel*

* CDMA/Direct Sequence Spread Spectrum

3. Locations of Sites for Experiments and Equipment to be Installed

As per Items 5 and 13 of the application, the following information is provided.

CT2/PCI experiments will be conducted at the following BNR and Northern Telecom sites using equipment developed by Northern Telecom and other vendors. In addition, field trials may be conducted at selected customer premises located within a 30 mile radius of the BNR and/or Northern Telecom facilities.

BNR Inc.
1150 E. Arapaho Road
Richardson, TX 75081

Equipment: 100 Base Stations
50 Handsets

Northern Telecom Inc.
2100 Lakeside Boulevard
Richardson, TX 75082

Equipment: 10 Base Stations
20 Handsets

Northern Telecom Inc.
685A E. Middlefield Road
Mountain View, CA 94039

Equipment: 30 Base Stations
40 Handsets

Northern Telecom Inc.
4001 Chapel Hill-Nelson Highway
Research Triangle Park, NC 27709

Equipment: 75 Base Stations
75 Handsets

BNR Inc.
35 Davis Drive
Research Triangle Park, NC 27709

Equipment: 25 Base Stations
25 Handsets

The CDMA spread spectrum experiments will be conducted at the following sites BNR sites, and potentially at customer premises located within a 30 mile radius of these facilities, using equipment developed by Northern Telecom and other vendors.

BNR Inc.
1150 E. Arapaho Road
Richardson, TX 75081

Equipment: 500 Experimental units

BNR Inc.
35 Davis Drive
Research Triangle Park, NC 27709

Equipment: 500 Experimental units

4. Description of CDMA/Spread Spectrum Tests

Technical Evaluation

The technical evaluation planned will be a two phase process. The first phase will be a laboratory evaluation and measurement process to determine propagation properties and robustness of CDMA radios inside buildings. The second phase will be field experiments to verify the laboratory results for both in-building environment and the urban/suburban environments.

The purpose of these measurements and analysis is to determine how spread spectrum technology will perform in a crowded user environment. Environments such as tall buildings, business and shopping complexes, and airports all differ in unusual interference patterns and properties. The natural radio propagation conditions of the Richardson and Research Triangle Park areas, as well as the effects of such natural conditions, such as rain, storms, foliage, etc., will also be taken into effect.

BNR also intend to evaluate the use of CDMA/Spread Spectrum technologies for low power microcell communications in the frequency bands requested. The usable range for different power levels and propagation characteristics, as well as performance of hand-held personal communications devices, will be evaluated.

Laboratory Evaluation

BNR will undertake a series of laboratory measurements before conducting any field trials. These lab measurements will assess the effect of various interfering signals on signal bit-error-rate and the radio performance as a function of the power of the desired signal and the power of the interference signals. These tests will be conducted both inside buildings and outside in a typical urban environment. Measurements relating to multipath, shadowing, propagation and attenuation through walls, building structures, foliage, trees, etc., will be made in both settings.

Field Measurements

These measurements will concentrate on the actual interference effects of other active users of the requested radio bands in the Richardson, Texas and Research Triangle Park, North Carolina areas. The field measurements made will be similar to those conducted in the laboratory environment, including bit error rates, signal propagation, fading and attenuation, and multipath interference.

In conducting these tests, BNR will coordinate its use of the spectrum with existing users of the spectrum and other experimental license applicants operating in the area. Most of these tests will be conducted in and around the Richardson and Research Triangle Park areas, with the majority centering around the BNR office complexes at the addresses noted above.

In addition, portable laboratories in five vans (at both Richardson and Research Triangle Park), equipped with the appropriate transmitters, receivers and test equipment will be used. This will allow multiple field test locations to be used for gathering results. BNR also believes that it will be necessary to do some limited tests with moving handsets to understand the effects of fast changing propagation conditions and the Doppler effects on the robustness of the CDMA technology and the communication channel.

The results from all our lab and field measurements will be documented, and will be used by the company as a basis for characterizing and predicting the performance of our CDMA technology.

Field Testing

Additional field trials under this license will be conducted within our company premises as in-house trials. These trials will consist of microcell wireless access to the company telephone equipment in the Part 15.247 bands. Microcells will be developed and placed at various locations, allowing a limited number of users to have wireless access. Northern Telecom's customers located near Northern Telecom or BNR facilities will also be given the opportunity to participate with us on an experimental trial basis in the microcell CDMA wireless links.

BNR anticipates that there will be at least 3 customer trial sites, where BNR will install up to 24 microcells per site, with a maximum of 200 portable handsets per site. To develop wireless networking capabilities, and to evaluate them, BNR plans to link these trial sites with point-to-point 5.7 GHz radio links, using Spread Spectrum technology. This will allow BNR to investigate personal communication networks to a greater depth.

This field testing phase will allow BNR to complete its customer testing and evaluation of this technology. It will give BNR sufficient technical and customer perception data to determine the market needs and acceptance of its CDMA technology.

The sites for these market trials have not yet been determined. In selecting these sites, BNR will coordinate its spectrum usage with existing licensed users. When they have been determined, the locations of the sites for the tests in the field trial phase will be supplied to the Commission prior to any installation or operation of equipment at the customer sites.

<u>Appendix A</u>

Northern Telecom's Comments on the FCC NOI
Related to PCS Evolution
Gen. Docket No. 90-314

noting in this context that the low power nature of the PCS keeps the emissions of individual in-building stations confined to areas of a few hundred square yards.

A significant portion of the 930-960 MHz band is assigned to studio transmitter link (STL) service. The assignment rules for this service suggest filling the band from the "bottom up".[16] This policy has clustered the unoccupied channels in the upper areas of the band in many places. Although not based on a detailed survey, the unoccupied portion of the 930-960 MHz band may be expected to provide sufficient spectrum to support the initial low power PCS for most metropolitan centers. In areas where the existing fixed service usage is heavy, and there is insufficient room for PCS, it may be desirable for there to be some migration of fixed services to other bands, such as 18 and 31 GHz. In metropolitan areas the Commission may wish to accept no new assignments in the 942-960 MHz bands, and to review carefully renewals in areas where PCS capacity is needed and it is practical for the fixed service to migrate to higher frequency bands. This procedure, of sharing with existing users, coupled with careful review of expansion, should make available sufficient spectrum over the near term without disruption to existing services.

The current domestic allocations of spectrum in the various bands 930 MHz through 960 MHz are assigned to the Fixed service and the Mobile service for Government and non-Government use. However, footnote 705 of the International Table of Frequency Allocations[17] allocates the band 890-942 MHz to the radiolocation service on a primary basis in the United States. The low power PCS may have difficulty sharing with the radiolocation service due to the very high power and wide range of the radiolocation service. The Commission may wish to review the general usage of the 890-942 MHz band by the radiolocation service and to restrict its usage to the 902-928 MHz (ISM band) band, so as to avoid interference with the low power PCS. No new assignments for the radiolocation service should be made in this band (outside of the ISM band), and existing licenses (if any) should not be renewed without careful review of future service requirements.

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[16] 47 C.F.R. § 74.503(a).

[17] 705 Different Category of service : in the United States, the allocation of the band 890-942 MHZ to the radiolocation service is on a primary basis (see No. 425) and subject to agreement obtained under the procedure set forth in Article 14.

For purposes of compatibility with other North American administrations, the Commission should be aware that the 944-948 MHz and 948-952 MHz bands are currently being considered for PCS in Canada.[18] The shared use of the 930-960 MHz band would provide interworking capability between the two countries. This would be of significant benefit for both service providers and manufacturers. Northern Telecom urges the Commission to plan its PCS allocations in concert with other administrations in North America.

Northern Telecom suggests that all low power PCS equipment should make full use of the low power PCS exclusive bands (930-931 MHz and 940-941 MHz) by means of the PCI protocols. The shared use of the 930-960 MHz bands would only be permitted by means of the PCI protocols which can, by signaling on the control channels, direct the use of channels suitable for the local area. This is necessary to prevent interference with the fixed service operations. The PCI standard channel assignments and signaling is outlined in the Annex to this submission. PCS base stations for private residential use would be restricted to the exclusive bands (930-931 MHz and 940-941 MHz). Public access and private business base stations, for which additional channels are needed for traffic capacity, would be able to make use of the shared bands subject to suitable constraints of sharing with fixed service users.

Northern Telecom recommends that there be no radio licensing requirements for any low power PCS handsets. There should also be no radio licensing requirements for low power in-building PCS base stations operating in the PCS exclusive bands. It may be desirable to apply frequency coordination procedures to PCS base station equipment which operates in bands shared with other services. If the Commission believes it does not have the authority to accomplish this objective, Northern Telecom recommends that Congress be asked to modify section 307(e)(1) of the Communications Act to exclude from licensing the low power PCS equipment operating in the PCS exclusive bands. Northern Telecom further suggests that blanket licenses be awarded on an interim basis to equipment manufacturers until such legislation is passed.

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[18] See Government of Canada, Department of Communications, "Spectrum Utilization Policy for the Fixed, Mobile, Radiolocation and Amateur Services in the Band 896-960 MHz", SP 896 MHz, Ottawa February 1990.

3.6.5 Band Development and Characteristics

An early introduction of low power PCS will most easily be achieved with the assignment of spectrum in the 900 MHz region. Two factors contribute to this choice of spectrum: radio propagation characteristics favorable to indoor and outdoor PCS environments, and the current availability of cost-effective RF technology for the 900 MHz region.

Propagation at 900 MHz has been researched by Bell Northern Research and other institutions. These frequencies are well suited for the low power PCS environments. Compared to low frequencies, e.g. 49 MHz, efficient antennas can be constructed which are completely contained within a pocket-sized telephone. However, as the frequencies are increased, antenna efficiencies are reduced. For example, 1800 MHz antennas are less efficient than antennas at 900 MHz. Attenuation through walls and partitions also tends to be lower at 900 MHz than at higher frequencies, such as 1800 MHz. This along with the reduced attenuation through obstacles, along with greater antenna efficiency allows a considerable reduction in transmitted power for the same coverage region. A reduction in transmitted power improves battery life and also lessens potential biological safety concerns.

The 900 MHz PCS equipment will also immediately benefit from mobile and cellular radio technology, volume manufacturing experience for the mass market, and the immediate availability of a wide range of test equipment. PCS products can be developed quickly by combining presently available RF technology with advanced digital modulation and channel allocation techniques. Recent advances in silicon and BiCMOS technology will enable the realization of inexpensive, low-power, fully-integrated transceivers operating below 1GHz.

3.6.6 Planning Longer Term PCS Development

The proposal in the preceding section addresses the early introduction of PCS in the 900 MHz band. This early introduction is necessary for market development and to begin to put into place the network support needed for the PCS. The spectrum assignment in the 900 MHz band will, however, likely be insufficient for the long term development of PCS and future public land mobile telecommunications systems. Further spectrum allocations will therefore be necessary to allow the development and expansion of PCS, international coordination, and the integration with other services. The review and development of such spectrum allocation should take advantage of the opportunity at the 1992 WARC to make the changes needed in the international table of frequency allocations to permit future PCS and mobile services development. The new spectrum should become available domestically in the years soon following the 1992 WARC.

There will be a need for sufficient spectrum to accommodate traffic growth of low power PCS. The estimates referred to in section 3.2 indicate a minimum long term requirement of 60 MHz for personal communications services. Although there would be advantages if this amount of spectrum could be made available in the 900 MHz band, this does not appear to be practical. Hence, the requirement must be planned for in the 1 - 3 GHz range, with careful consideration for existing spectrum policy and usage.

There is a need for international compatibility of spectrum allocations to accommodate global usage of personal communications services. There are advantages to the customers, the service providers and manufacturers from international compatibility and standards. The customers benefit from the capability of international roaming. The existing very high volume of international travel makes this worthwhile now, and it will have greater value as additional travel shrinks the world into a global village. The service providers benefit from the increased traffic resulting from the increased number of roamers possible because of international compatibility. Experience shows this is likely to be an important factor, as some mobile cellular operators derive significant revenue from roamers. In addition, the manufacturers benefit from the international standards and the resulting economies of scale of manufacturing for global markets.

Finally, there is a need for the PCS allocation to include applications such as the wireless residential access systems.[19] These wireless residential access systems have a requirement for 40-60 MHz, and it would greatly assist compatibility of services if this were included in the new low power PCS band. Such an expansive allocation is also consistent with the notion that PCS is properly thought of as an integral part of the telecommunications infrastructure, and not merely an adjunct to cellular or cordless phones.

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[19] See for example, BELLCORE, "Generic Framework for Universal Digital Portable Communications System (PCS)", TA-FSY-001013, March 1990.

When planning the long term spectrum policy, which will require an additional allocation for PCS, Northern Telecom suggests that the Commission evaluate proposals based on the following criteria:

- international compatibility (on a regional and global scale)
- sufficient bandwidth for initial traffic estimates
- potential for expansion due to growth in traffic
- compatibility with other applications such as residential access
- compatibility with established users of the band

These factors suggest that a future allocation for PCS in the 1710-2290 MHz band should be given serious consideration. An allocation of approximately 120 MHz in this band would support both PCS and residential access services. Use of this band for PCS has considerable support in other areas, particularly in Europe, and its adoption by the Commission would facilitate the early development of suitable standards, and accelerate the date by which extended PCS could become available.

The difficulty with this band, however, is that it is very heavily utilized by both government and non-government fixed and mobile services. Any change in domestic assignments must take into consideration the effects on existing usage. It will be necessary to review current usage and to take steps for long range planning to move existing users, if necessary. This will likely mean a freeze on assignments in these bands to fixed services in urban areas, and gradual conversion of some fixed services to other technologies such as higher frequency bands or optical fibers. Changes in spectrum assignments are never easy. They are quite affordable and practical, however, if they are done as part of a plan with a time scale to accommodate the regular equipment amortization and replacement cycle. It is also very important to plan the new service technology to permit the sharing of bands on a suitable basis during the transition period as spectrum assignments change. As outlined above, the low power PCS are ideally suited to band sharing with many other services.

Several subsections of the 1710-2290 MHz band are assigned for the exclusive use of the Government. These include the 1710-1850 MHz band and the 2200-2290 MHz band. These are utilized for mobile, fixed and certain space services. Legislation before the Congress suggests a review of current government requirements and usage of spectrum.[20] Under this proposal, suitable unused frequencies would be reassigned to the non-government sector. Unused channel assignments in these bands, if any, would be ideally suited for PCS development.

In the long term, it would be desirable to restrict the growth of fixed systems in the bands selected for PCS operation, particularly in the large metropolitan areas. The major demand and high traffic areas for personal communications service are inside the urban areas. In contrast, the greatest requirement for point to point fixed service links is for long distance communication across rural areas. The replacement of radio links in many urban areas has already begun due to the blockage of line of sight paths in urban centers. Many of these fixed service applications utilize high bandwidth fiber optic links between the city centers and the point-to-point radio link stations located at the edge of the urban area.

To achieve a global allocation for personal communications, it will be necessary to study and plan for domestic allocation changes, to work in the international arena to achieve a consensus on the band for designation before the 1992 WARC, and to plan to support the designation of the band at the conference. The Commission should quickly adopt long-term PCS policies so that it can more effectively participate in this international allocation process.

4.0 STANDARDS AND ARCHITECTURE

In its Notice of Inquiry, the Commission asks a number of questions regarding standards for both "CT-2" and "PCN Type" equipment and services (Paras 29 and 30). Central to this inquiry is the role the Commission should play in adopting such standards.

In some areas (e.g. allocating spectrum, adopting emission standards to reduce interference, and adopting channelization plans), Northern Telecom supports direct action by the Commission and has set forth herein its own recommendations for such action. In other areas, however, dealing with issues such as adoption of standards for

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[20] "Emerging Telecommunications Technologies Act of 1989", H.R. 2965.

common air interfaces and revision of numbering plans, Northern Telecom believes that the Commission should encourage standards groups (both on a national and international level) and other groups such as Bellcore to continue to develop consensus positions on these issues.

In several recent proceedings dealing with technical standards issues -- particularly the ISDN Inquiry and the Computer III Proceeding -- this Commission addressed similar questions concerning its role in adopting standards. In the First Report in the ISDN Inquiry, for instance, the Commission set forth its position as follows:

> The FCC's domestic policy on analogous issues of standardization has been generally not to adopt governmentally mandated technical standards which are relevant to the performance of telecommunications facilities, and to limit such standards to those that directly achieve statutory purposes, in an effort to minimize regulatory impediments to innovation and design flexibility. ... For example, we have been moving away from standards on radio transmitting equipment which go to the use of such equipment and limiting standards on radio equipment in our rules to those that address interference. ... It has been the position of the FCC that performance standards may be desirable, but that they should be non-governmental voluntary ones adopted under the auspices of organizations such as those accredited by the American National Standards Institute (ANSI).[21]

Northern Telecom supports this position and believes the Commission should apply this approach to the area of personal communications. To date, for instance, standards groups such as the EIA Committee on TR45 have been successful in gaining consensus adoption of a common air interface standard for cellular systems in the U.S., and there has been good success in administration of the North American numbering plan. As the Commission notes, many private, governmental, and quasi-governmental groups are active in setting standards both at national and international levels in this field. If this consensus process of setting standards breaks down, or otherwise proves inadequate, however, the Commission should pursue a number of other options to avoid unnecessary delays in implementing PCS in the domestic marketplace. It is vital that the U.S. quickly develop standards that are designed for the U.S. market. A failure to set such standards would slow the implementation of PCS in America. Other regions are well on their way to setting standards for PCS to meet their particular needs. Thus, the Commission should express a willingness to intervene, if necessary, to ensure that appropriate standards are timely adopted.

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[21] Integrated Services Digital Network, 98 FCC2d 249 (1984) at para. 64.

To facilitate and accelerate the adoption of technologies and standards for PCS, Northern Telecom has included in this submission discussion material and specific recommendations on network and access services.

Figure IV.1

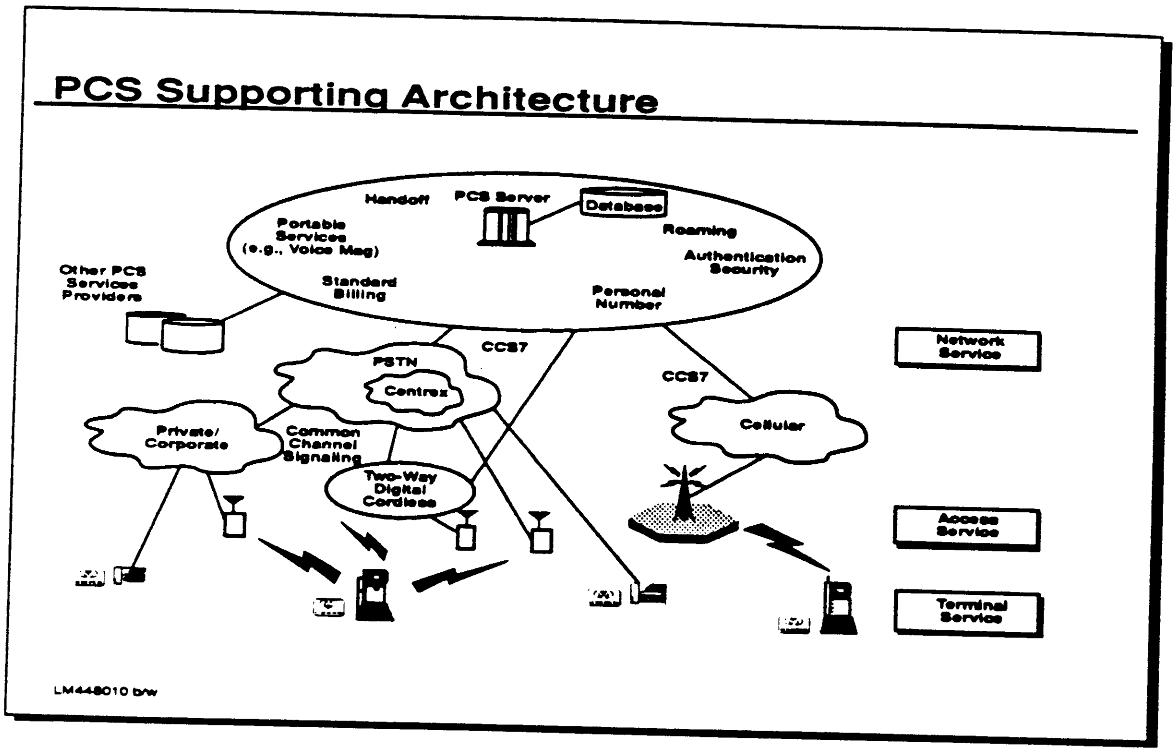


Figure IV.1 illustrates an architecture needed to support PCS. There are two levels of service intelligence recognized in this architecture (in addition to the terminal specifications): (i) network; (ii) access.

The issues associated with system and service interoperability are key to full implementation of PCS on a ubiquitous basis.

4.1 Network Service Intelligence and Standards

There are a number of capabilities which will drive network functionalities and standards requirements to support a seamless personal communications services environment. There are three that are particularly important for review at this stage: personal telecommunications number, personal identification and authentication and consolidated billing.

1. **Personal Telecommunications Number** - As a PCS user roams across systems, calls designated for him need to be routed to the supporting system closest to him. The supporting system must therefore recognize that the PCS user (identified by his personal telecommunications number) is in its vicinity, and deliver the incoming call. PCS systems will serve different personal telecommunications numbers dynamically when the user wants to originate or receive calls in the geographic area where the user is located. The standardization of personal telecommunications numbers and their relation to the North American Numbering Plan is complex. A great deal of work by the industry is needed to design a personal telecommunications number scheme which will facilitate rapid deployment of PCS. We recommend the following principles be followed when designing the personal telecommunications numbering plan:

   a. do not force the users to change their current dialing habits if at all possible;
   b. the selected design must not become a bottleneck in the growth of PCS, i.e. we must not run out of personal telecommunications numbers in the next 20 to 50 years;
   c. a reasonable evolution path must exist for a smooth transition from today's numbering to personal telecommunications numbering.

2. **Personal Identification and Authentication** - In order to allow users the flexibility to gain access to personal communication services from multiple systems and at the same time guard against fraudulent use, sophisticated and consistent mechanisms must be designed and standardized to verify and authenticate the identity of the accessing user.

3. **Consolidated Billing** - In a PCS environment, a user may roam to an area served by a different operator than the one providing the service subscription. It would not be practical to obtain bills from each service provider into which the user roams. Hence, charges incurred in different systems while the user roams should be consolidated by the PCS service provider from which the user obtained

the PCS subscription. This service requires billing record compatibility across all participating service provider networks and systems.

Figure IV.2

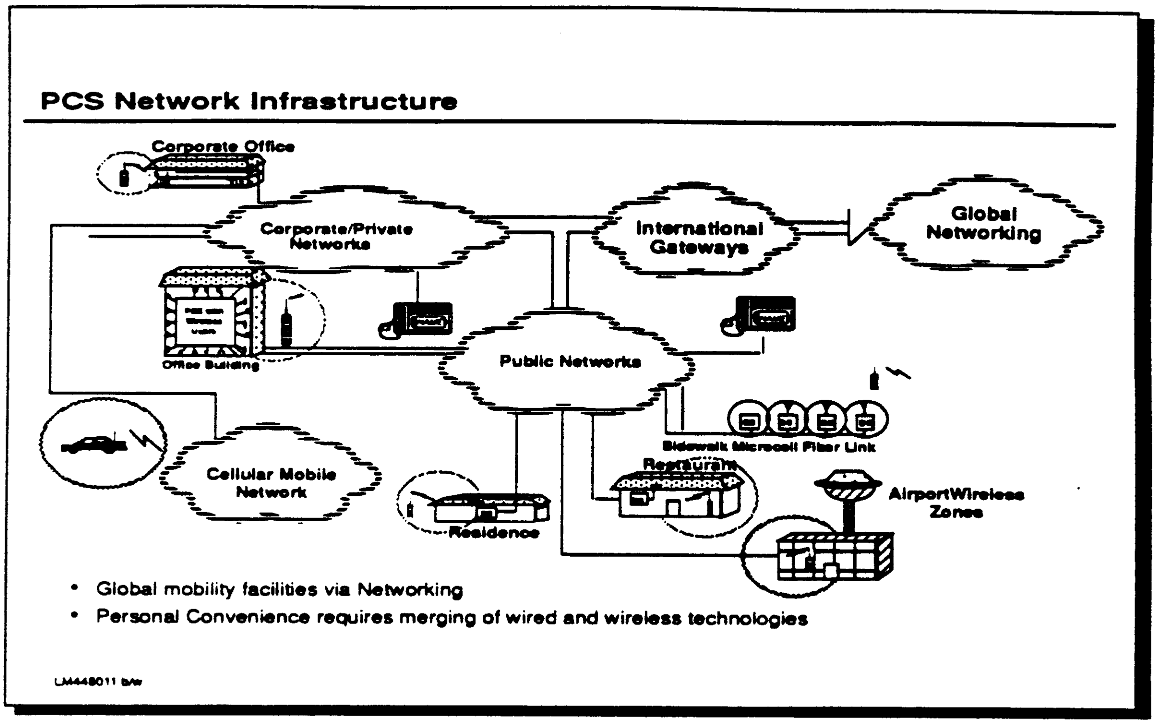


Figure IV.2 illustrates the overall network context under which the PCS environment must be supported. The mobility management functions and the service networking capabilities need to be designed in this broad context to ensure roaming capabilities across cellular systems, private networks, public networks and international networks.

Other services and capabilities which require standardization to permit operation across systems include:

- user location registration databases and tracking mechanisms;
- call handover procedures and protocols as users move from one cell to an adjacent cell;
- selected basic and supplementary service such as Custom Local Area Signaling Services (CLASS), which would be available through a variety of operators' systems while the user is roaming;

- call screening;
- charge advice.

To facilitate the orderly distribution of network service intelligence across different network elements, a flexible architecture must be defined. Advanced Intelligent Network Concepts and functional partitioning schemes form an excellent basis for structuring the PCS networking standards development activities and should be applied in this context.

4.2 Survey of Current Mobile Services Standards Activities

A number of different access technologies are being proposed to meet the wireless access requirements for PCS. These technologies have been optimized to satisfy different criteria (technology, regulatory environment, subscriber modularity, reach, speech performance, etc.) and may not be appropriate for all scenarios without modification. The principal access technologies under review are:

1. TDMA in North America;

2. CDMA proposals for North America;

3. Pan European CT2;

4. DECT/GSM and PCN standards for Europe;

5. PCI Standard: Low power Personal Communications Interface

In Europe, the CT2 based telepoint service is being deployed, and DECT standards are being negotiated. In North America, the TDMA-3 proposal has been adopted by the cellular industry, while there are a number of different proposals and experiments underway to test the suitability and advantages of CDMA in different commercial and residential environments.

Most of the proposals have emphasized the merits of their radio access techniques in addressing the requirements for personal mobility. These techniques can be evaluated in terms of a number of different attributes, some of which are given below:

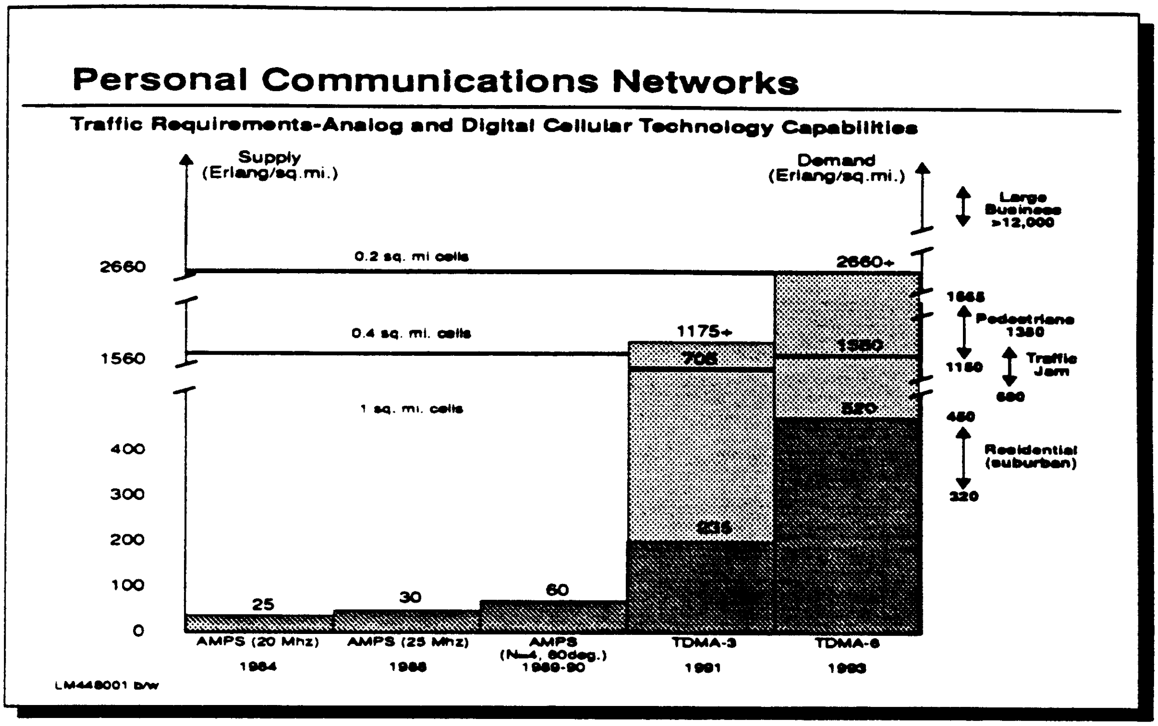
- suitability in various spectrum availability scenarios;
- spectrum efficiency;
- implementation complexity;
- technological maturity, component availability and cost.

4.2.1 TDMA in North America

Over the last few years, there has been rapid growth in the demand for cellular telephones, and a concomitant expansion in the deployment of cellular service. U.S. cellular subscriber penetration is estimated at about 5 million units in 1990, and is expected to double by 1993. The average growth rate of cellular subscribers in the last three years has been approximately 25 to 40% per year, and is predicted by most market analysts to continue at about this rate for the next several years. In the six years since the first commercial deployment of cellular service in America, the installed base of analog cellular systems are almost reaching capacity in the largest urban geographic areas. As discussed below, there have been, and will continue to be, dramatic increases in cellular capacity to meet these needs. Nonetheless, new PCS services are needed to complement, not replace, cellular service.

The overlaying or replacement of analog radio with digital radio technologies is expected to increase by several fold the capacity of analog cellular systems. Figure IV.3 is a representation of the capacity of analog and digital (TDMA) cellular technologies from a supply point of view and the capacity demands of various user categories. The supply and demand categories are represented in Erlangs per square mile, based on random call interarrival times and traffic patterns, with 2% blocking probabilities using standard Erlang B assumptions for uniformity.

Figure IV.3



The figure illustrates the capabilities of current technologies, capacity improvements expected in the migration of the cellular base to digital radio technology, and the potential of advanced cellular networks to provide a network infrastructure for low power microcellular personal communication applications.

In 1984 the first commercial cellular systems in the U.S. were based on analog AMPS using 20 MHz of radio spectrum in the 800 MHz band. This results in approximately 25 Erlangs per square mile of traffic carrying capacity based on an N=7 cell reuse pattern.

With the expansion of operational spectrum systems in 1988, an additional 5 MHz of spectrum was granted that allowed a 30% rise in traffic carrying capacity. With further improvements in cell reuse (N=4) and 60-degree cell sectorization, an additional improvement of about 60% is achieved. These improvements are in progress with deployment underway in a number of areas in the U.S.

In 1989 the U.S. cellular industry adopted the TDMA standard for advanced digital cellular systems. In general, the number of voice channels per radio channel can be increased by a factor of three with the use of TDMA-3. However, due to the non-linearity of the Erlang-B Assumptions the resultant capacity increase, as measured in Erlangs per square mile, is an almost four-fold increase in moving from analog AMPs to TDMA-3. This is reflected in Figure IV.3.[22] Additional improvements in capacity as a result of further advances in DSP technology permit six voice channels per radio channel. This is referred to as TDMA-6.

Deployment of the initial phase of digital technology in the U.S. is expected in the 1991 timeframe, with subsequent enhancements in capacity continuing in the following 12 to 24 months.

This additional dimension of capacity improvement is the result of deployment of microcellular radio technology. This technology will also permit increasingly smaller cell sizes and increase significantly the capacity of cellular systems. As modeled in Figure IV.3, the effect of reducing a cell radius 42% and 55% results in capacity increases of 200% and 400%. Microcellular technology in cell sizes of 0.2 square miles offer the potential of 2,600 Erlangs per square mile.[23]

The following technical factors are likely to enable an evolution to microcellular system deployment and the subsequent capacity increase:

- Effective Dynamic Channel Allocation (DCA) schemes; the need for DCA results from the variable nature of very small cell contours. In addition, by optimizing C/I requirements, DCA could enable a capacity improvement beyond that achieved through cell radius reduction.

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[22] Cell reuse (N=4) and 60-degree cell sectorization are reflected in Figure IV.3 for 1988 - 1993.

[23] The use of even lower-power, and correspondingly lower cost radios is predicted to decrease the cell size even further. With microcell sizes of a few hundred feet or less, additional growth in capacity is expected to increase by a factor of several hundred. Additional increase in the TDMA capacity would be achieved by a further reduction of cell sizes (microcells and picocells).

- More effective frequency reuse schemes made possible by the interference reduction enabled by better antenna technology.

- Various schemes addressing the higher handoff rate that would result from a vehicular microcellular system:
  - faster handoff processing
  - larger umbrella vehicular cells overlaid with pedestrian picocells thus limiting the handoff rate
  - cost & size reduction of micro/pico base stations enabled by lower transmitted power and newer technology

The principal advantages of exploiting the TDMA technologies and cellular spectrum to support low power radio access for PCS as well as high power vehicular radio access are given below:

a. one terminal for both high power cellular and low power PCS environments;
b. high spectrum efficiency;
c. economies of scale resulting from a common platform for vehicular and low power PCS systems.

The current cellular network infrastructure and the TDMA cellular radio interface standards were defined and largely optimized for high speed, high power vehicular traffic. The advent of digital cellular will increase substantially traffic handling capabilities within the existing spectrum allocation. New technologies such as CDMA/Spread Spectrum and microcellular TDMA have the potential of providing considerably higher capacities. However, the scope of the newly emerging personal communications services increases the number of potential users by an order of magnitude or greater. Therefore, Northern Telecom recommends that additional spectrum above 1 GHz be allocated conforming with worldwide agreements for these new personal communications services.

4.2.2 CDMA Proposals for North America

A number of different systems have been proposed for North America, and currently no standards have yet emerged. The CDMA systems proposals potentially promise some very desirable features that cannot be easily matched by the present narrowband systems. Among them is an ability to resist multipath interference; a soft capacity limit in which overloading of systems is manifested as a graceful degradation of speech quality, rather than total blocking of service to additional users; and the potential to share spectrum with other fixed users. However, these systems are generally more complex and require more switching and signaling resources. While technical issues such as accurate signal power modulation, control between small and large base station distances, and the requirements for a large quantity of spectrum to address future growth are being investigated, the CDMA technology merits serious investigation of the potential for significant bandwidth improvements and widescale application. The experiments authorized by the Commission should provide much needed information on the viability of this access technology for PCS. Northern Telecom supports further trials and exploratory development of this technology.

4.2.3 Pan European CT2

The CT2 technology is specifically designed for low power, low cost, non-vehicular traffic. It is fast becoming a Pan European standard for Advanced Digital Cordless telephones and holds promise to be adopted worldwide. A large number of North American equipment manufacturers such as Northern Telecom are actively exploring advanced versions of this technology with other equipment vendors abroad. Strong market demand, combined with cumulative technology and design experience will drive the CT2 components down the cost curve rapidly and result in very cost competitive digital low power equipment.

In the United Kingdom, a CT2 based telepoint service is being deployed at present. This initiative has encouraged other European countries, including France, Germany, Netherlands, Spain, Belgium and Finland to sign a Memorandum of Understanding leading to the adoption of CT2 standards in those countries. This has prompted the European Telecommunications Standards Institute, ETSI, to now consider CT2 as an interim European telecommunications standard. Outside of Europe, CT2 equipment is being tested and placed in service in the U.S., Canada, Australia, Singapore, Malaysia and New Zealand.

There are a number of enhancements that can be made in the European low power CT2 standard, which are addressed in the PCI Standard section.