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

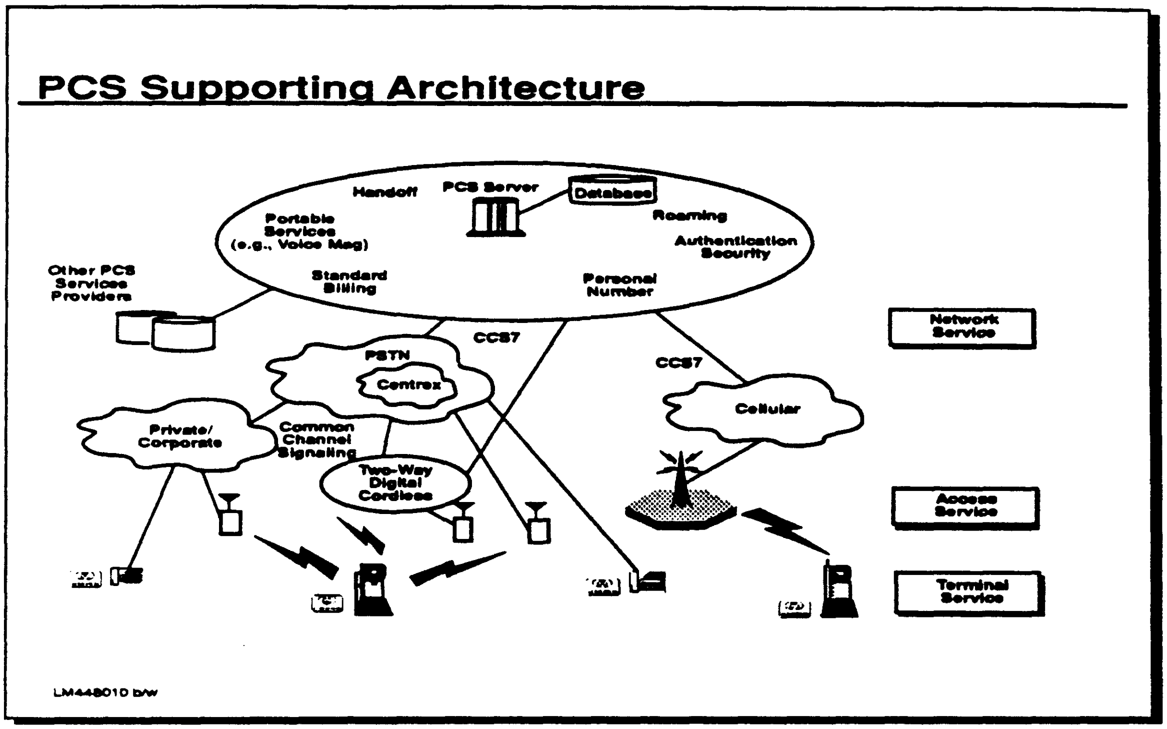



Figure IV.1 illustrates an architecture needed to support PCS. There are two levels of service intelligence recognized in this architecture (in addition to the terminal specifications): (i) network; (ii) access.

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

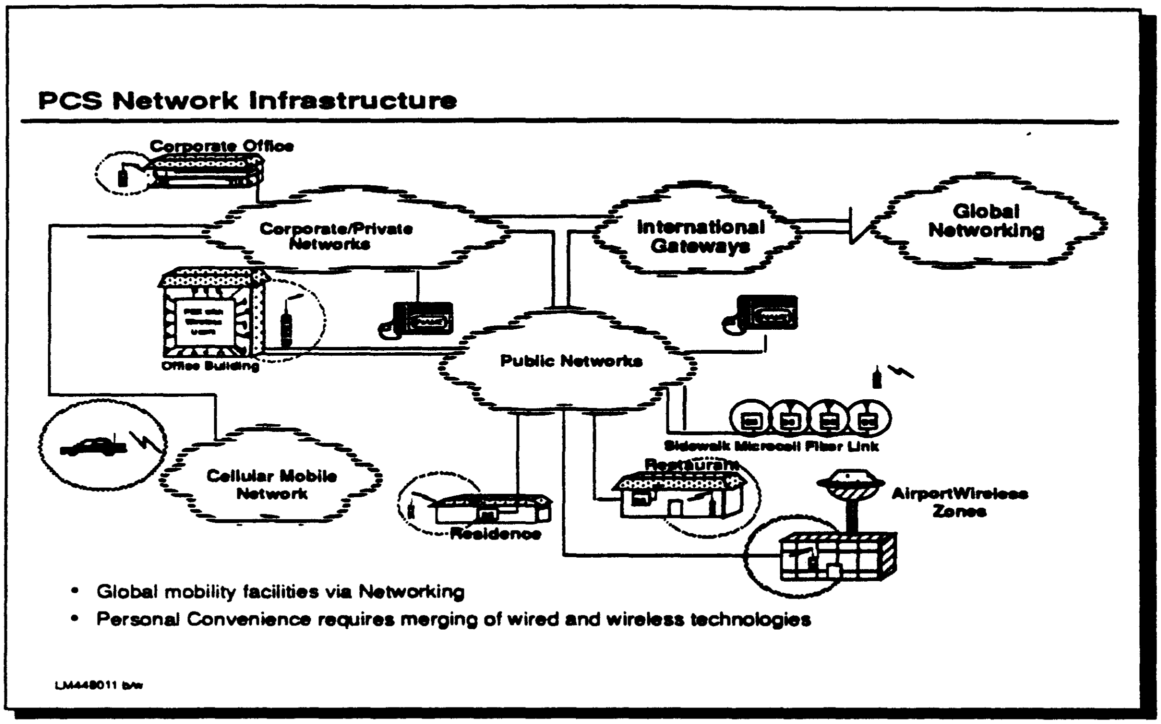



Figure IV.2 illustrates the overall network context under which the PCS environment must be supported. The mobility management functions and the service networking capabilities need to be designed in this broad context to ensure roaming capabilities across cellular systems, private networks, public networks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

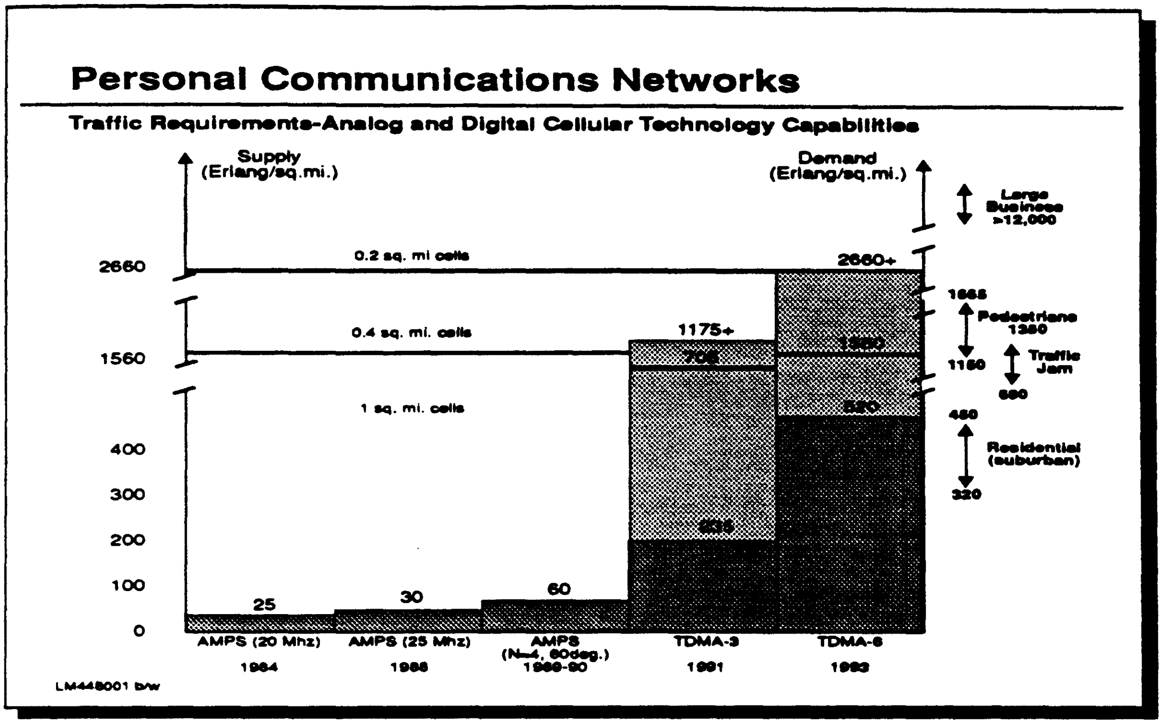
- suitability in various spectrum availability scenarios;
- spectrum efficiency;
- implementation complexity;
- technological maturity, component availability and cost.

### 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.

#### 4.2.4 DECT/GSM and PCN Standards Evolution in Europe

In Europe, Digital European Cordless Telecommunications (DECT) development activity is in the preliminary stage, while Groupe Speciale Mobile (GSM) standards are closer to completion. The U.K. is implementing DCS 1800, which is based on the GSM standard operating at 1.8 GHz. This standard is currently being modified by ETSI to develop a Pan European PCN service, and is expected to be completed by the end of 1990. Even after this standard setting is finalized, it is expected that experiments and design trials will delay this European PCN deployment until after 1993.

#### 4.2.5 PCI Standard: Low Power Digital Standard Proposal for North America

Northern Telecom believes there is significant market potential for advanced, low power digital cordless technology. As a result, Northern Telecom has developed a number of significant personal communication system enhancements to European CT2 in proposing the PCI protocols as the standard for North American application. Details of these improvements are described in the PCI specification annexed to this submission. The key enhancements are summarized as follows:

A. **Frequency Agility** - PCI is defined with 2 MHz of dedicated channels over 930-931 MHz and 940-941 MHz, with flexibility to share spectrum with other users over 930-960 MHz band.

B. **Common Signaling Channels** - A number of TDMA signaling channels are defined to speed up call set-up and to decrease scan time. This will result in higher capacity and performance, extend battery life, and facilitate signaling for advanced supplementary value-added services in the PCI standard.

C. **Handover Procedure** - A handover handshake procedure is also defined to facilitate ease of handover using the common signaling channel.

D. **Security** - Encryption algorithm and procedures are also defined to allow secured communication.

Compatibility with the European CT2 CAI standard is also maintained to ensure that common hardware components can be used between CT2 CAI and PCI based equipment to maximize the manufacturing scale economics.

## 5.0 REGULATORY ISSUES

As an equipment manufacturer engaged in a variety of research and development activities dealing with personal communications services, Northern Telecom's primary interest and concern deals with the technical issues previously addressed in these comments. Nonetheless, Northern Telecom would like to briefly comment on several regulatory issues addressed by the Commission in the Notice of Inquiry, since the successful deployment of PCS will depend, inter alia, on the prompt resolution of these issues.

### 5.1 Regulatory Restrictions on Services

As the Commission notes, many of the main issues surrounding personal communications services -- which PCSs are needed, where in the spectrum those services should be provided, how much spectrum should be allocated to them, and how the services should be regulated -- are unresolved at present. Technologically as well, the issues of how to provide PCSs are largely undefined, and are receiving a great deal of attention from industry participants at the present time. As a general matter, Northern Telecom believes that it is vitally important that the Commission implement a regulatory framework which encourages and allows for new PCSs, limit its regulation to deal with concerns that have been traditional Commission issues in the radio area, such as interference and efficient utilization of bandwidth, and not unnecessarily seek to regulate the manner in which these new services are provided or the context of such services. Such a policy is in line with recent Commission pronouncements and decisions in other dockets,[24] and will serve to encourage the benefits of competition between multiple PCS offerings. To the extent regulation of such services comes under State, as opposed to Federal jurisdiction, Northern Telecom recommends that the individual states also adopt policies which promote such competition.

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24 See e.g. the Commission statement dealing with Commission involvement in setting ISDN standards quoted previously

### 5.2 Numbering Plans

A long-term issue deals with the need to supplement the numbering plan currently in effect in the U.S. with a personal telecommunications number (PTN) approach, under which a telephone number could be permanently assigned to an individual without regard to location. Such recommendations are under discussion (see e.g. the article Calling People, Not Places by Irwin Dorros, Communications Week, September 3, 1990) and are technologically feasible. Northern Telecom believes that implementation of a PTN numbering approach is an essential corollary action to be taken in conjunction with the licensing of PCS providers. Adoption of such a plan will greatly enhance the usefulness and application of PCS services, and will lead the public to view such services as complementary parts of an overall access network. Northern Telecom recommends the FCC appoint Bellcore to be the administrator for the personal telecommunications numbering plan, and seek proposals for industry comment.

### 5.3 Licensing Handsets

In the NOI, the Commission notes that current Commission policies which except the need to license handset units (i.e. blanket licensing for cellular handsets and Part 15 treatment for cordless phones) may not be available for certain low power equipment used only in a home or office. Northern Telecom believes that it is extremely important that companies be able to manufacture and sell equipment to users without the need for them to obtain a radio license for PCS. Licensing requirements for handsets, in our opinion, would significantly delay and impede broad consumer acceptance of low power radio services. For the same reasons, Northern Telecom also opposes any user licensing requirements for so-called "Pico" base stations used in conjunction with in-building wireless PBX systems.

## 6.0 CONCLUSION

In response to the Commission's NOI, Northern Telecom has developed a broad yet practical vision of PCS. PCS should not be thought of as solely advanced cellular, or advanced cordless telephones, but rather as an integral part of the telecommunications infrastructure of the future. PCS, combined with other enhancements to the telecommunications network, will allow individuals to have seamless access to the telecommunications infrastructure, regardless of whether they are in the home, in the office or anywhere else in America.

While this vision of PCS is somewhat forward looking, there are some steps the Commission can and should take right away to ensure that a broad PCS will evolve. Indeed, the failure to act expeditiously will jeopardize the enormous potential benefits of these services for the American public and the telecommunications industry.

As an initial matter, Northern Telecom proposes that the Commission immediately allocate 930-931 MHz on a primary basis, and 930-960 MHz on a co-primary basis, for low power personal communications services as the first generation PCS. In order to facilitate the development of standards that will allow interoperability of these services throughout the U.S., Northern Telecom also proposes a PCI protocol standard employing advanced digital architecture with common channel signaling, a common air interface and call handoff procedures for these low power PCS systems. This proposed standard can be implemented quickly.

In order to meet the longer term needs for PCS, the Commission should begin the task of allocating additional spectrum in the 1710-2290 MHz band for future PCS systems. Such an allocation should take place in conjunction with the 1992 WARC to ensure international compatibility. In addition, the Commission should begin to address the difficult licensing, regulatory and standards issues that must be resolved in a timely manner in order that the deployment of PCS not be delayed.

The Commission's NOI is a good first step towards creating a robust PCS that is an integral part of an advanced telecommunications infrastructure. Northern Telecom has suggested a roadmap to continue that journey. The public interest will be well served by the U.S. implementation of a robust PCS, and Northern Telecom requests that the Commission take the necessary actions so that we may attain that goal.

Respectfully Submitted,

By________________
Albert Halprin
Stephen L. Goodman
Verner, Liipfert, Bernhard
McPherson and Hand
901 15th Street, N.W.
Washington, D.C. 20005
(202) 371-6000

Counsel for
Northern Telecom Inc.

Of Counsel:

John G. Lamb, Jr.
Northern Telecom Inc.
2100 Lakeside Boulevard
Richardson, Texas 75081
214-437-8000

Dated: October 1, 1990

BNR

Annex to

**Northern Telecom's**

Response to
NOI Gen. Docket No. 90-314
RM-7140
RM-7175

# PCI

# A Common Radio Standard for Personal Communications Interface

Issue 1.3
September 1990

## Introduction

This document describes the common radio interface specification for a Personal Communication Interface (PCI). This is based upon BNR studies of requirements for low power radio Personal Communications Services (PCS) ranging from single and multiple line residential "cordless" applications, public access applications, and large in-building wireless business communications applications. The interface makes use of moden digital modulation and access techniques to achieve a high traffic capacity and very high spectrum utilization efficiency. Dynamic channel allocation techniques are utilized to facilitate the efficient assignment of resources in high traffic applications. The dynamic channel allocation process is also well suited to shared spectrum assignments.

The specification addresses the interworking between fixed and portable radio units operating in the PCS band, including Public Access Services and Business and Residential Applications. This specification is based on the CT2 Common Air Interface Specification (MPT 1375 CAIS[1]) developed in the United Kingdom, and includes evolutionary enhancements and modifications to meet a broad range of PCS requirements.

The PCI specification consists of two parts:

1. The CT2 Common Air Interface Specification (CAIS) comprising:

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|---|---|
| MPT 1375 | dated May 1989 |
| Amendment 1 to MPT 1375 | dated November 1989 |
| Annexes A, B, C | dated November 1989 |
| Amendment 2 to MPT 1375 | dated February 1990 |
| The specification for UK Function "F" | released December 1989 |

   Copies of MPT1375 and various annexes are available from the U.K. Department of Trade & Industry, or from Mr. Craig Hall, Northern Telecom Inc., (615) 734-4000.

2. An Annex specifying enhancements to the CT2 CAIS.

   CT2 CAIS is an open standard. It deliberately leaves sections of the message space undefined in order to accommodate future expansion of services and facilities. CT2 already provides for the addition of data and security features. The Annex defines a standard implementation of these features.

[1] MPT 1375, "Common Air Interface Specification", Department of Trade & Industry, Radiocommunications Division, London SE1 8UA.

**Classes of Equipment**

There shall be two classes of equipment:

i ) Equipment meeting the provisions of the CT2 CAIS, operating in the PCS spectrum allocation.

ii ) Equipment meeting the provisions of both the CT2 CAIS and the annex of enhancements specified in this document. Equipment in this class, both base stations and terminals, shall be capable of interworking with equipment in class (i) above.

The remainder of this document is a draft of the annex which specifies the enhancements to the CT2 CAIS.

**Annex: Enhancements to CT2 CAIS**

Where applicable, reference to the relevant clause(s) of the CT2 CAIS have been provided. Acronyms are as defined in the CAIS.

## 1. Operating frequencies

The channel carrier center frequencies shall be:

$$(f_l - 0.05) + (0.05 \times n) \text{ MHz}$$

where n is the channel index,
and $f_l$ is the lower frequency band edge.

The same carrier frequency shall be used for transmission in both directions between fixed and portable stations.

The lower frequency band edge, $f_l$, is 900 MHz. The lowest channel index, n, is 1. The largest channel index is 1200. This provides for channel center frequency assignments in the range from 900 MHz to 959.95 MHz. Not all channel indices are allowed.

The PCS exclusive bands are defined by channel indices as follows :

| | | |
|---|---|---|
| 930-931 MHz | n = | 603,605,607,609,611,613,615,617,619. |
| 940-941 MHz | n = | 803,805,807,809,811,813,815,817,819. |

Within the index ranges 603-619 and 803-819 (inclusive) only odd numbers may be used.

| | | |
|---|---|---|
| 902-928 MHz | (ISM band) | n=43 to 559 |

Other indices, to specify a channel frequency outside the PCS exclusive bands, may only be used subject to constraints of sharing with other local users of the bands.
Within the index range 882-1040 only even numbers may be used.

Channels 603 and 803 are reserved for use for the common signalling channels. Channels 882, 884, 1038, and 1040 are also designated for common signalling channels where sharing conditions permit. Further signalling channels may be designated if required.

## 2. Common Signalling Channels

This section defines the structure of the common signalling channels (CSCs) and their usage. The purpose of adding CSCs to the CT2 CAIS is to provide the following improvements: call set-up to the base station with the strongest signal, thereby extending capacity and performance; faster call set-up, and decreased scan-time requirement at the portable stations, thereby extending standby battery life and facilitating the delivery of value-added services. Where equipment is intended to make use of the CSCs, the manufacturer shall make a declaration to this effect. Where such a declaration has been made, the equipment shall conform to the requirements of this section. The transmitters and receivers using the CSCs shall meet the RF performance requirements of the CAIS.

### 2.1 Common Signalling Channel Frequencies

Channels 603 and 803 are reserved for use as common signalling channels. Channels 882, 884, 1038, and 1040 are also designated as common signalling channels where sharing conditions permit. Further signalling channels may be designated if required.

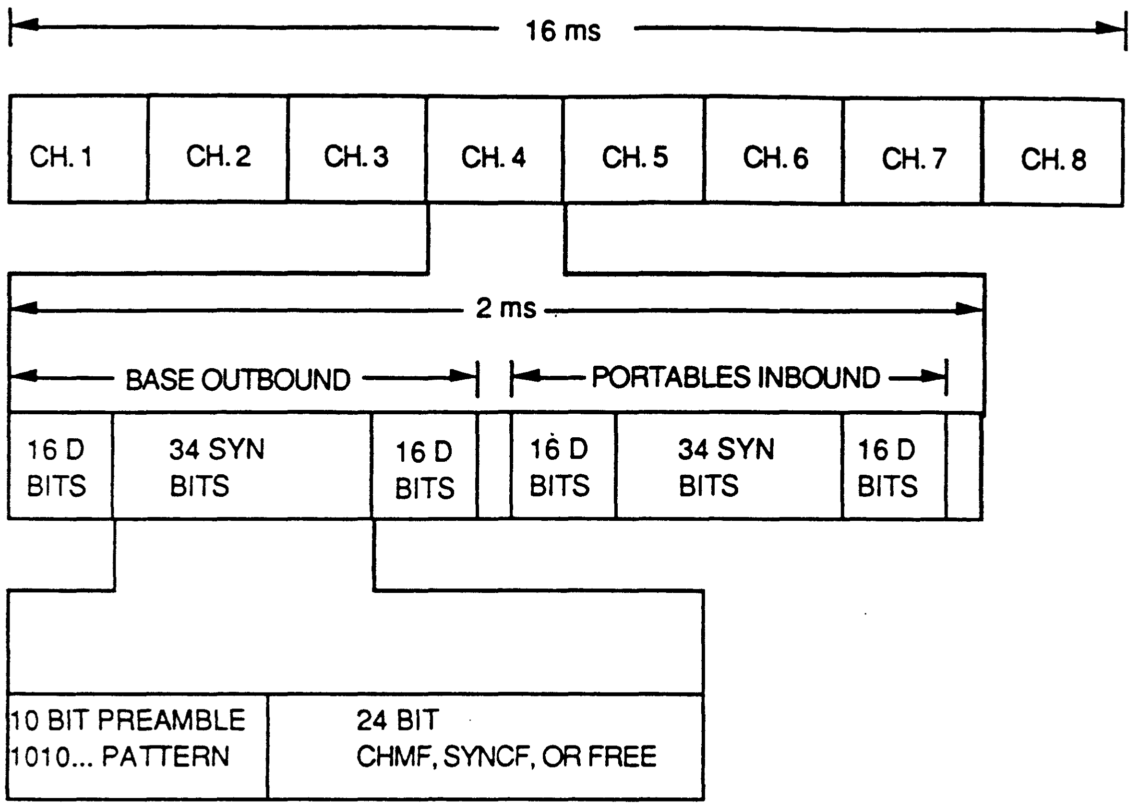
These signalling channels operate at frequencies as follows :

| Channel | Frequency (MHz) |
|---|---|
| 603 | 930.1 |
| 803 | 940.1 |
| 882 | 944.05 |
| 884 | 944.15 |
| 1038 | 951.85 |
| 1040 | 951.95 |

### 2.2 Multiplex Structure of the Common Signalling Channels

Each of the carriers reserved for CSC use supports eight CSCs in TDMA mode. Figure 2.1 shows the frame structure used to multiplex eight CSCs onto a given carrier. This frame structure shall be known as MUX4. The transmission rate and modulation technique shall be those specified in the CAIS, namely, 72 kb/s Gaussian-shaped FSK with peak deviation between 14.4 and 25.2 kHz under all possible data patterns. The RF envelope ramp up and ramp down profiles shall meet the requirements of the CAIS, part 1, figure 1.2. The burst structure of MUX4, shown in Figure 2.2, is identical to that of the MUX2 format of the CAIS (see CAI, part 2, figure 2.3). A burst is 66 bits long. Each inbound (CPP to CFP) burst follows 5.5 bit periods after the end of the outbound burst. The CPP synchronizes its timing to the CFP. Like MUX2, MUX4 contains two sub-multiplexes: the SYN channel and the D-channel. The SYN channel contains words which indicate the status of the channel, and is used to gain bit and burst synchronization. The 2 kb/s D-channel is used for layer 2 and 3 messaging, as well as to indicate the status of the channel.

Figure 2.1 & 2.2 : MUX4 Frame and Burst Structure




## 2.3 Dynamic Allocation of Common Signalling Channels

A base station shall be defined as a cordless fixed part (CFP) containing a number of radio fixed parts (RFPs), which are under common control, and their associated antennae. Only one CSC may be used at a given time by a CFP, no matter how many RFPs it contains. The particular RFP within the CFP that operates on the CSC may change from time to time. Every CFP shall also support calling channel detection and link set-up establishment in regular CT2 CAI mode, on the PCS exclusive channels, as described in the CAIS, part 2.

A CFP shall select a CSC on which to operate by the following algorithm:

i) Upon power-up or reset, the CFP shall scan all CSCs and select a free channel upon which to operate. A "scan" and a "free channel" shall be defined as in the CAIS, part 1, appendix B, section 18.3.4. Briefly, a free channel is one where the received field strength is below 40 dB relative to 1 µV/m, or failing that, the channel with the lowest field strength. Where a number of free channels exist, manufacturers shall use such selection strategies as to ensure random or uniform distribution of the CSCs in use, in accordance with the CAIS, part 1, Appendix B, section 18.3.3.

ii) A CFP may have given up its CSC because the radio supporting it was needed to service a call on a traffic channel. When a radio does become available to re-establish a CSC, the original CSC shall be scanned and if free shall be the one selected for use.

iii) If interference is encountered on the CSC in use, a CFP may drop it and re-establish on a new carrier frequency (of the ones reserved for CSCs) and/or time-slot. However, two re-establishments shall not be initiated within a time period of $T_{cscr}$ ($T_{cscr}$=10 s) of each other.

## 2.4 Multiple Access Protocol on a Given CSC

A CFP may put the CSC into four modes:

broadcast mode - broadcast information for all CPPs,
emergency broadcast mode - vital information for all CPPs,
paging mode - information for a specific CPP, and
conversation mode - a communication link established to a specific CPP.

The SYN and D channels contained in the base outbound burst shall be used to indicate the current mode.

### 2.4.1 Broadcast Mode

Broadcast mode is the normal mode during idle periods. The CFP shall set the SYN channel word to FREE. FREE is a 24 bit pattern with low autocorrelation and low cross correlation with the 24-bit words CHMF and SYNCF, defined in the CAIS, part 2, section 2.1.1. The presence of FREE in the SYN channel means that the inbound burst in the next frame may be used by any CPP. The D-channel contains the CFP identification, BID, as well as any value-added layer 3 messages that the CFP wishes to broadcast to CPPs. Layer 3 messages in broadcast mode shall be continually re-broadcast for a period of at least $T_{rb}$ ($T_{rb}$=15 s) or until there is a change in operating mode. This minimum broadcast time is to ensure that CPPs can go for reasonable periods of time without decoding the D-channel (to save power), yet will not miss any broadcast information.

Normally, a CPP registers with the base station whose CSC is received with the highest field strength. The CPP then periodically monitors that CSC (and may monitor others as well). If the CPP fails to receive broadcasts on the CSC for a period of greater than $T_{mon}$ ($T_{mon}$=5 s), then it shall attempt to register with another base station. If registration fails, the CPP shall revert to regular CT2 CAI mode.

### 2.4.2 Emergency Broadcast Mode

Emergency broadcast mode is used when the CFP has broadcast information for all CPPs in its cell and wants to force reading of the information. The CFP shall set the SYN channel word to CHMF, and the D-channel address code word shall contain a PID, to be known as ALL. ALL is a specific PID which is not used by any handset as a PID. The presence of ALL as the PID also indicates that the inbound burst may be used by any CPP. The D-channel contains any vital information that the CFP wishes to broadcast to CPPs. Layer 3 messages in emergency broadcast mode shall be continually re-broadcast for a period of at least $T_{fcyc2}$ ($T_{fcyc2}$=1.4 s) or until there is a change in operating mode. This ensures that CPPs can "sleep" for reasonable periods of time between checking the CSC, yet will not miss emergency broadcast information.

### 2.4.3 Paging Mode

Paging mode is used for call set-up from the CFP to the CPP. The CFP shall set the outbound SYN channel word to CHMF, and the D-channel address code word shall contain the PID for the CPP in question. No other portable may transmit during the inbound timeslot until the SYN channel word reverts to FREE, or the PID reverts to ALL.

### 2.4.4 Conversation Mode

The CFP puts the CSC in conversation mode after contacting a specific CPP, or in response to a link request from a CPP. The CFP shall set the SYN channel word to SYNCF, and the D-channel address code word shall contain the PID for the CPP in question. No other portable may transmit during the inbound timeslot until the SYN channel word reverts to FREE, or the PID reverts to ALL.

### 2.4.5 Multiple Access Contention Resolution

It may occasionally happen that two CPPs, seeing the CSC is free (i.e. in broadcast or emergency broadcast mode) both attempt simultaneously to begin transmitting on the same inbound timeslot. In this case a collision may occur. A CPP which fails to receive the expected CFP response to its link request shall wait a random number of MUX4 frames before again attempting to transmit on the CSC. The CPP shall ensure that the CSC is in broadcast or emergency broadcast mode before re-attempting transmission.

## 2.5 Layer 2 and 3 Message Formats

The layer 2 and 3 messages shall be formatted as described in the CAIS, parts 2 and 3. The "Link re-establish on a given channel" layer 2 message (CAIS, part 2, section 3.5.6) shall be extended to two octets in order to specify the increased number of channels in the allocation.

Subsequent sections shall refer to address code words (ACWs). These are 64-bit (two MUX4 frame) packets of information. Each ACW is preceded by a synchronization burst that contains the D-channel synch word, SYNCD, as its final 16 bits. Thus, the transmission of an ACW requires three frames, or 48 ms. The synchronization burst format and ACW formats are described in the CAIS, part 2, sections 3.3 and 3.4.

## 2.6 Uses of the Common Signalling Channels

### 2.6.1 Registration of a CPP

The CSCs facilitate roaming and higher performance by providing a means for registration of CPPs with the nearest (strongest) base station. Once a CPP has registered with a base station, incoming calls (CFP to CPP) can be set up quickly, as the CPP need only monitor that base station's CSC for paging messages.

The CPP, having scanned all CSCs, chooses a base station on which to attempt registration. This will normally be the base station whose CSC gave the highest field strength reading. The CPP waits until the CSC is in broadcast or emergency broadcast mode (see section 2.4 above) before beginning transmission.

Registration proceeds according to Figure 2.3. The CPP begins transmitting in MUX4 on the inbound time-slot with its SYN channel word set to CHMP. The D-channel ACW sent is a LINK_REQUEST containing the CPP's PID and the desired base station's BID. If a response is not received from the CFP, the CPP follows the contention resolution procedure of section 2.4.5 above.

The CFP normally responds by setting the SYN channel word to SYNCF to put the CSC in conversation mode. It sends a LINK_GRANT ACW which contains a LID for subsequent handshaking.

The CPP completes the handshake with an ID_OK ACW. It also sets its SYN channel word to SYNCF for the remainder of the registration process. Layer 3 is then initialized, and registration proceeds as it would in CT2.

If registration cannot be completed on a CSC, then the CPP shall revert to CT2 CAI operation within the PCS exclusive allocation.

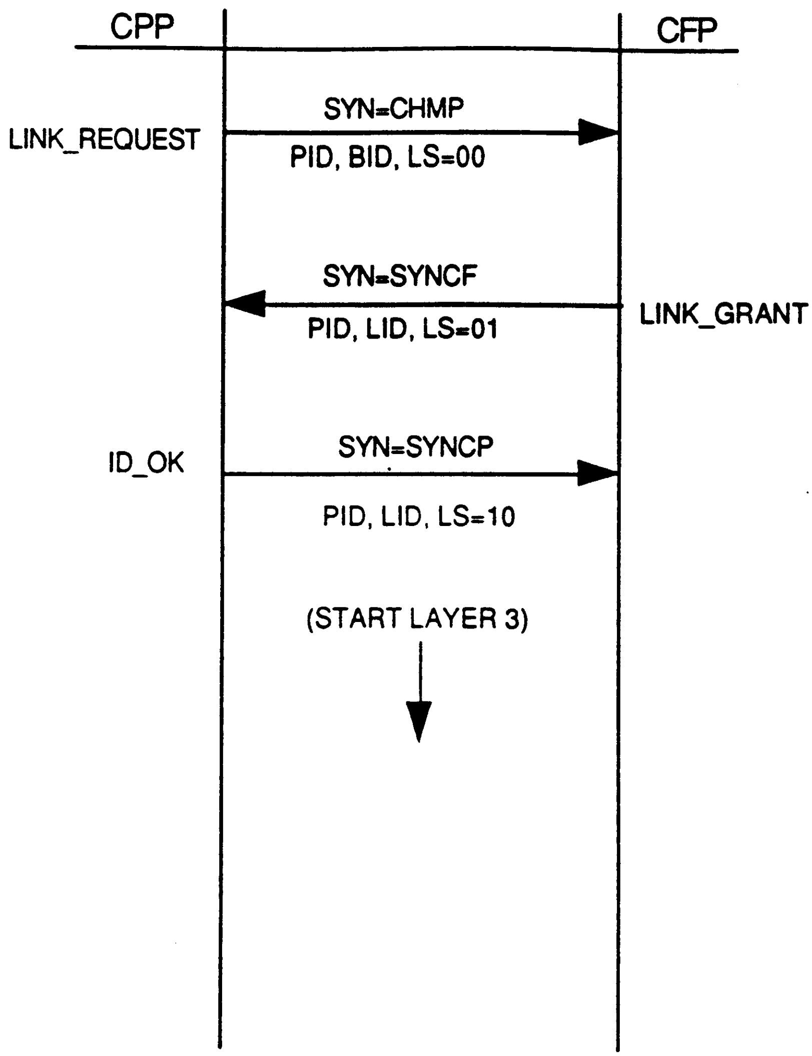



Figure 2.3 CPP Registration

2.6.2 Call Set-Up From CFP to CPP

Refer to Figure 2.4. The CFP puts the CSC in paging mode by setting the SYN channel word to CHMF and by issuing an ID_OK ACW that contains the CPP's PID and the base station's BID. This paging message (which may also be part of a multiple ringing poll) is continually re-broadcast until either the CPP responds or a timeout of $T_{fcyc2}$ ($T_{fcyc2}$=1.4s) expires. If the timeout expires, the CFP shall attempt call set-up on a traffic channel in regular CT2 mode, as described in the CAIS, part 2.

The CPP normally responds by setting its SYN channel word to SYNCP and issuing a LINK_REQUEST ACW.

The base station responds by setting its SYN channel to SYNCF and issuing a LINK_GRANT ACW that assigns a link reference LID for the call. The CSC is now in conversation mode.

The CPP echoes back this LID in an ID_OK ACW.

The CPP and CFP now agree on a traffic channel for call set-up to proceed on. The CFP always has the last word in this process, but the CPP has some choices. The CFP sends a list of candidate free channels to the CPP. The CPP checks one or more during the idle part of the MUX4 frames, and confirms its first choice back to the CPP.

Having agreed upon a traffic channel, the CFP issues a "Link Re-establish on a Given Channel" ACW (see CAIS, part 2, section 3.5.6) and switches to the agreed-upon channel. It then begins transmitting in MUX2 and sends an ID_OK ACW containing the LID for the call. If it fails to receive a reply within a timeout period of Tsu (Tsu=100 ms), it tries another free channel from the list for a further period of Tsu. This procedure may continue for up to a maximum of five free channels.

The CPP checks the agreed-upon channels, starting with the preferred choice. When it sees the ID_OK ACW from the CFP, it issues its own ID_OK ACW to complete the handshake. Layer 3 is then initialized and call set-up proceeds as in regular CT2.

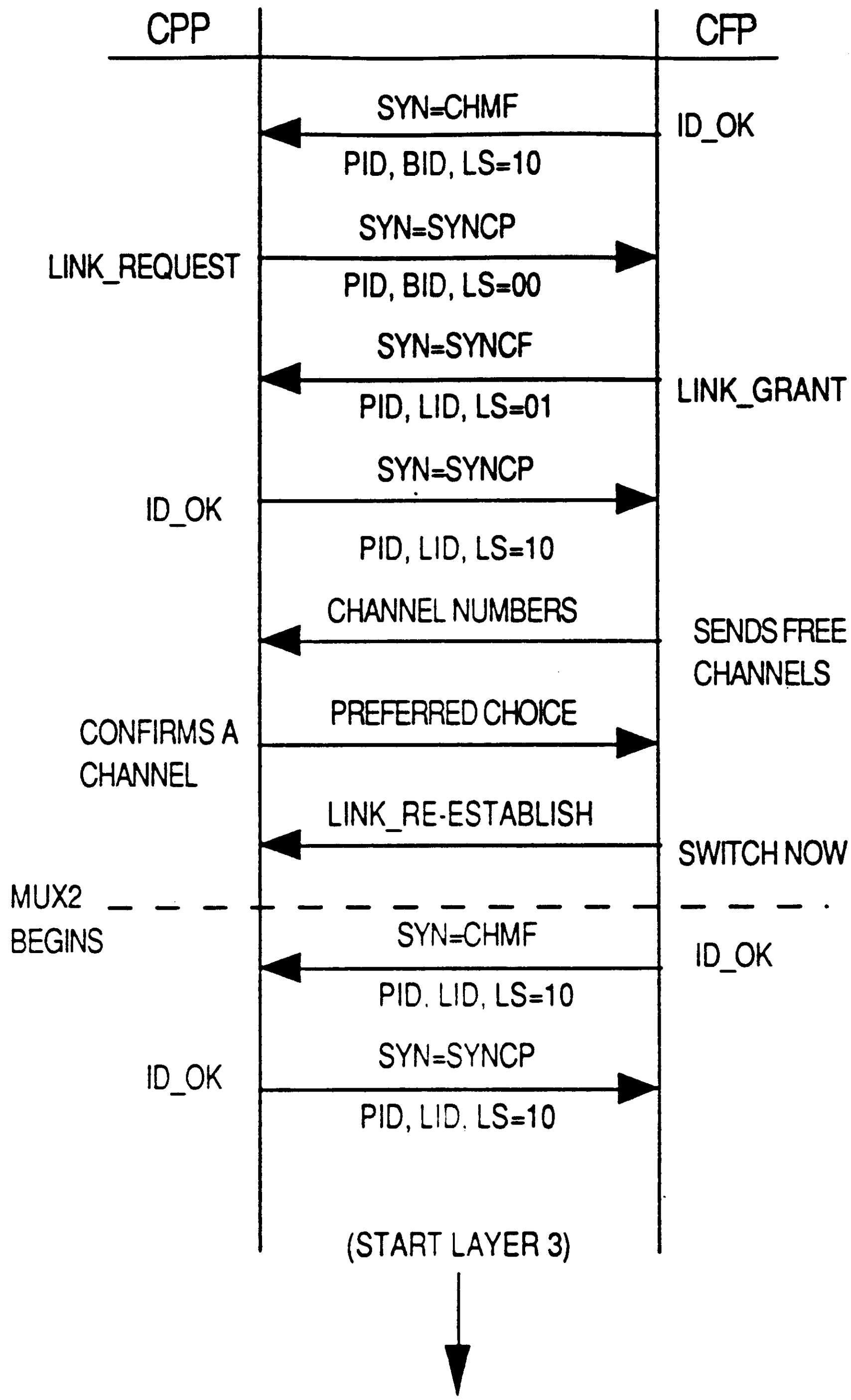



Figure 2.4 Call Set-Up From CFP

2.6.3 Call Set-Up From CPP to CFP

The call set-up procedure from CPP to CFP, shown in Figure 2.5, is identical to the CFP to CPP call set-up procedure, except that the initial CFP ID_OK paging message is absent. If call set-up cannot be completed on the CSC, then the CPP shall attempt to set-up the call on a traffic channel in regular CT2 CAI mode.

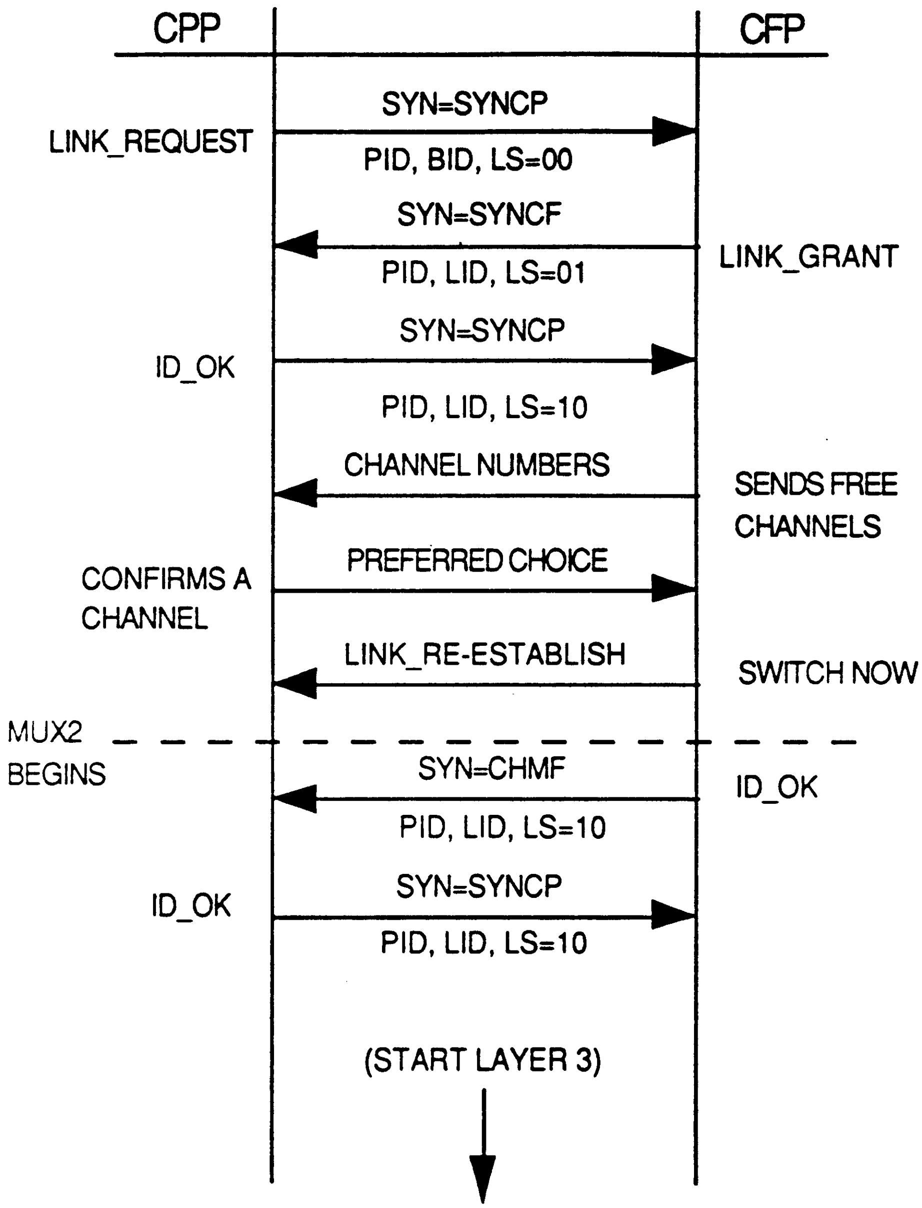



Figure 2.5 Call Set-Up From CPP

### 2.6.4 Value-Added Services

The CFP may send layer 3 broadcast messages to CPPs in either broadcast or emergency broadcast mode, as described in section 2.4, above.

CPPs may send layer 3 messages to the CFP, without having to establish a traffic channel, by following the registration procedure.

## 3. Hand-over

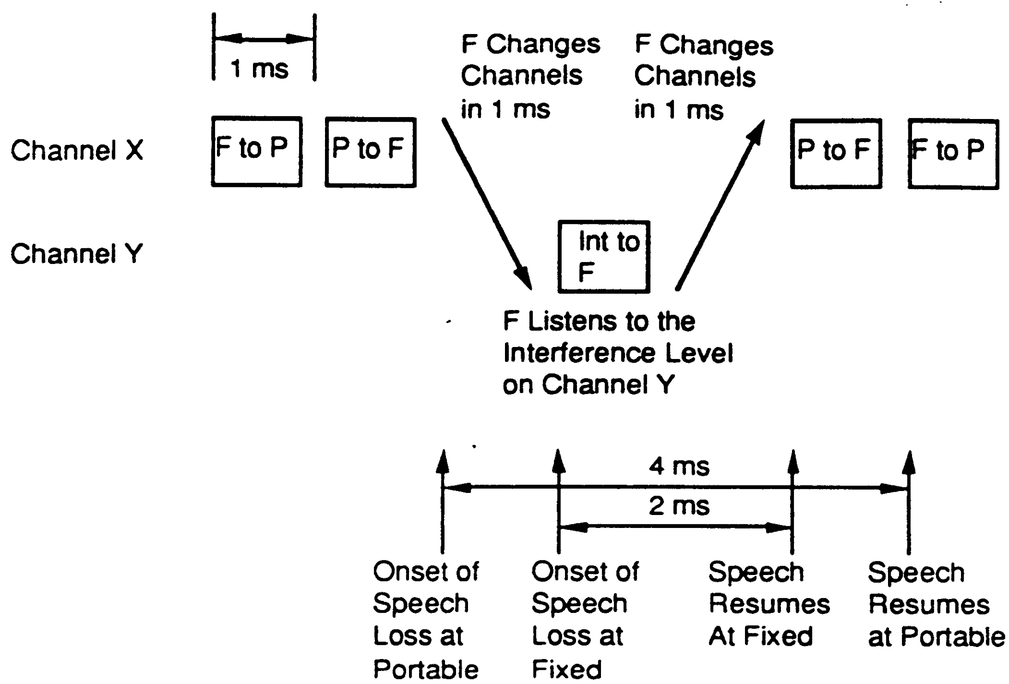
### 3.1 Link Re-establishment in the Same Base Station (Intra-cell hand-over)

This type of hand-over, i.e., to a new frequency on the same base station to avoid interference, is caused by changes in channel usage. (A base station is defined as a CFP containing a number of radio fixed parts (RFPs) and associated antennas which are under common control). Typically, the interference occurs instantaneously with no warning. For example, another call established on the same or adjacent channel in a distant cell may lead to unacceptable interference for a call in progress.

The CFP and CPP maintain a list of up to five candidate free channels to hop to if and when interference suddenly arises. This list is maintained routinely, not just when a hand-over is required. If there is an idle RFP at the base station, the idle RFP maintains the list. If there is no idle RFP available, then the RFPs servicing calls occasionally hop away from their calls to check the interference level on candidate channels, then hop back to their calls. These interruptions may be about 4 ms in duration as illustrated in Figure 3.1. (This case, however, seldom occurs. The probability that there is no idle radio at the base is approximately equal to the blocking probability, i.e. $< 1$ % for a business communication system.) The CFP keeps the CPP informed of the list of free channels via D-channel messages. The CPP checks one or more of the candidates and confirms to the CFP over the D channel the candidate channel with the lowest field strength from its perspective.

Link re-establishment on a different channel in the same base station may occur upon request from either end in an existing link. The CPP and/or the CFP may try to re-establish a link at any time when the received signal quality is degraded for longer than $T_{pq}$ ($T_{pq}$=40 ms). Link re-establishment is permitted only after a period of at least 300 ms from a previous link establishment or re-establisment.

Figure 3.1: **Checking for a Free Channel**




Action at the CFP:

After transmission or reception of a "Link Re-establish on a Given Channel" message (CAIS, part 2, section 3.5.6), the CFP immediately switches to the given channel and begins transmitting ID_OK in MUX2 over that channel (with CHMF in the SYN channel, PID, and the last received link reference in the LID field in the D channel). The transmission should last for a minimum of $T_{re}$ ($T_{re}$ = 100 ms) unless a response from the CPP is received. Two eventualities exist:

i) The link is re-established when the CFP accepts a MUX2 response (ID_OK) from the target CPP before the expiry of the timeout. The B-channel connection is then re-established.

ii) No recognized response is received before the expiry of the timeout. In this case a new RF channel is selected (from the list of candidate free channels) and the CFP sends ID_OK on this channel for a period of $T_{re2}$ ($T_{re2}$=50 ms). This process continues for a total of up to five free channels.

Action at the CPP:

After transmission or reception of a link re-establishment message, the CPP checks the given channel (and the list of candidate free channels) for the presence of CHMF and the appropriate IDs in the D-channel for a time not exceeding $T_{re} + 4 \cdot T_{re2}$. Two eventualities exist:

i) The CPP detects CHMF in the SYN channel and the expected ID_OK in the D channel. The CPP then responds in MUX2 with SYNCP in the SYN channel and ID_OK in the D channel, completing the handshake.

ii) No recognized response is received before the expiry of the receive time. The CPP may then rescan the Common Signalling Channels and initiate a call set-up procedure to the base station with the maximum relative received signal strength. On successful re-establishment of the radio and signalling links the call is re-routed to the appropriate base station by the CCFP.

Link re-establishment attempts must cease when the 10 s handshake timeout ($T_{hlost}$) expires.

### 3.2 Link Re-establishment to a Different Base Station (Inter-cell Hand-over)

This type of hand-over is typically caused by movement of the CPP out of a cell. The received signal strengths at the CFP and CPP gradually decrease as the CPP moves out of the coverage area of the base station.

Link re-establishment to a different base station may be initiated from either end in an existing link.

Action at the Origination CFP/Destination CFP:

The origination CFP alerts the CCFP of the possible need of a hand-over to a different base station. Adjacent base stations are instructed to monitor and report on the quality of the received signal from the CPP. The base stations also identify one or more free channels up to a maximum of five. The CCFP selects the best base station (i.e., the destination CFP) and free channels and reports this information to the origination CFP.

The origination CFP issues a D-channel message (Monitor Channel(s)) to the CPP to check a list of candidate free channels. The CPP responds on the D-channel with its preferred free channel. The destination CFP is sent this channel number and commences transmitting (and receiving) in MUX2 over this channel (with CHMF in the SYN channel, PID and the last received link reference in the LID field in the D channel). On receipt of a signal indicating that the destination CFP has begun transmitting in MUX2, the origination CFP issues a D channel link re-establishment message (Link Re-establish on a Given Channel To a Different Base Station) and sends a signal to the destination CFP indicating that the hand-over has begun. The destination CFP continues to transmit in MUX2 after receipt of this signal for a period of at least $T_{re}$. The origination CFP continues to operate on its original frequency but switches to transmitting (and receiving) in MUX2 (with CHMF in the SYN channel, PID and the last received link reference in the LID field in the D channel) when the link re-establish message is acknowledged. Speech is muted. Three eventualities exist:

i) The destination CFP accepts an ID_OK ACW from the CPP. The link is re-established on the destination CFP. The CCFP signals the origination CFP to release the link.

ii) No recognized response is received before the expiry of the timeout. In this case the destination CFP selects a new RF channel (from the list of candidate free channels) and the CFP sends ID_OK on this channel for a period of $T_{re2}$ ($T_{re2}$=50 ms). This process continues for a total of up to five free channels.

iii) The origination CFP accepts a MUX2 response with the correct ID code from the target CPP. The B-channel connection is then re-established. (The hand-over to the destination CFP failed.)