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*Chapter 8*

# A REVIEW OF PERSONAL COMMUNICATIONS SERVICES

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## ABSTRACT

PCS is an acronym for Personal Communications Service. PCS has two layers of meaning. At the low layer, from the technical perspective, PCS is a 2G mobile communication technology operating at the 1900 MHz frequency range. At the upper layer, PCS is often used as an umbrella term that includes various wireless access and personal mobility services with the ultimate goal of enabling users to freely communicate with anyone at anytime and anywhere according to their demand. Ubiquitous PCS can be implemented by integrating the wireless and wireline systems on the basis of intelligent network (IN), which provides network functions of terminal and personal mobility. In this chapter, we focus on various aspects of PCS except location management. First we describe the motivation and technological evolution for personal communications. Then we introduce three key issues related to PCS: spectrum allocation, mobility, and standardization efforts. Since PCS involves several different communication technologies, we introduce its heterogeneous and distributed system architecture. IN is also described in detail because it plays a critical role in the development of PCS. Finally, we introduce the application of PCS and its deployment status since the mid-term of 1990's.

**Keywords:** telecommunication network, wireless communications, cellular telephone, personal communications services, personal communications network, intelligent network, broadband PCS, narrowband PCS.

## 1. INTRODUCTION

Communication is an important and necessary part of human life. People can perform face-to-face chatting with each other within a certain range. It is the most direct communication mode. When one person wants to talk or send messages to another person who is far away from him, long-distance communications occur, which need the support of long-distance communication techniques. In the long history of human kind, people have invented various methods to communicate with each other. A popular way is postal service, in which textual messages are delivered between communication partners by the form of letters. Nowadays, in addition to letter delivery, postal service has been used in many other areas of human life. To speed the communication, people have also created many effective and interesting ways in the old days. In many ancient countries, important and time-critical messages were carried by riders with strong horses. Some ancient persons had also trained birds to fly between two communication partners for carrying messages. In ancient China, even fire had been used in military communications. The Chinese central government had built Great Wall to defend the country. Military stations were distributed on the Great Wall every a certain distance. Once the soldiers in one station found the enemy, they would set fire. The light and heavy smoke generated by the fire notified the neighbour stations that enemy was coming. The neighbour stations would continue to set fire to notify their neighbours. Thus, all the military stations would be notified one by one. This type of communication mode was very smart, which embodies the wisdom of ancient Chinese. Constrained by the development levels of science and technology, the long-distance communications were very inconvenient and costly in old days. What is more, the real voice cannot be delivered.

All this was completely changed when electrical power was utilized in long-distance communications. The revolutionary change began when Bell invented the telephone. It was the first time that people can hear each other even when they are not within the direct voice communication range. Since then, the techniques used in long-distance communications have experienced persistent and remarkable innovations. Wired transmission was the first step, in which sound wave is transmitted by the form of electronic pulse. Nowadays, fixed telephone network formed by wired transmissions between wired stations is very popular in the world. People can make a call as long as a telephone set connecting to the telecommunication network is available. People communicate with each other from wired station to wired station in fixed networks. Initially, only copper lines were used to transmit the communication signals resulting in low transmission capacity. To meet the ever-increasing communication demands, the optical fibers have replaced the copper lines to provide huge communication capacity and high transmission quality in wired transmission. The transmission change from electronic pulse to optical pulse is a great innovation in wired communication, by which people are not worried about the limited transmission capacity. In modern communication networks, the transmission bottlenecks mainly come from the limited processing capability of communication devices. Immediate textual transmission has also been realized by the invention of fax machines. Wired communication greatly overcomes the limitation of communication distance, but still relies on whether the communication partner is in the specific location at a specific time.

Wireless transmission and mobile communication were the second step, also the most important step in the development of communication technologies. Cordless telephone is the simplest form for mobile communication, which has relaxed people from the fixed telephone terminal to a small movement range around the fixed terminal. Well, strictly saying cordless telephone is not a real case of mobile communication since it only corresponds to the replacement of a limited length of copper line. However, mobile communication has more fruitful meaning and can provide global roaming service. The mobile communication technology has evolved from the first-generation to the third-generation within the past twenty years. The first-generation (1G) mobile communication network uses analog technology and only provides voice communication service. The second-generation (2G) mobile communication network appeared in the early 1990's, which introduces digital technologies into wireless transmission and provides many new services. The third-generation (3G) mobile communication network is currently a hot topic although it has not been widely deployed. 3G is expected to provide high speed data and high quality voice communication services. The development of mobile communication further releases people from the limitation of location. People can communicate with each other by handheld mobile devices (mobile phone or PDA) in all the places covered by the mobile communication networks. Other new technologies for storing and retrieving communication contents, e.g., voice mail, have further freed modern communications from the limitation of time.

In addition to mobile communication, another historic invention is the Internet in 20th century. The Internet has deeply changed the world and pushed us into a so called information society. By it, both information distribution and information resources sharing are more convenient. The Internet also has provided powerful functions to benefit person communications. For example, people can chat with each other using some popular instant messenger. Lots of persons with the same interest can also chat together in a virtual chatting room. In addition, both video and audio data can be easily transmitted on the Internet since it has much higher bandwidth than cellular networks. Hence, personal communications by video and/or audio data transmissions have been popular through the Internet. Thus, people will have the feelings of face-to-face chatting although they are far away from each other. In addition to personal video chatting, video conferences are also widely used in many organizations or companies, which help reduce the cost. In the telecommunication networks, no matter telephone networks or cellular networks, the products of video terminals are also available but not popular due to high cost.

Generally speaking, personal communications have experienced four remarkable stages by far, i.e., non-electricity transmission, telephone networks, wireless and mobile communication, and the Internet. Nowadays, the four stages still exist together and their technologies are also widely used in the world. With the evolvement of communication technologies, more and more personal communication services can be provided to benefit our living. Cost is a critical issue in communications. For the communications with special purposes, e.g., military communications, security is also an important issue. We briefly compare the characteristics of the four development stages of communication technologies in terms of communication quality, cost and security. Obviously, the non-electricity transmission has low communication quality with high communication cost and low-level communication security. Telephone network can provide high quality voice communication with medium-level cost and high-level security since it uses wired transmission. Wireless and mobile communication can provide medium-level quality voice communication with high-level cost and low-level security since it uses air transmission. The Internet can provide both video and voice communication with medium-level quality, low-level cost and medium-level security.

In daily life, the vast majority of us will communicate with each other, no matter where we are, through various handheld communication devices. With the social development, people have proposed more and more personalized communication demands. Scientists and engineers need to develop more and more powerful communication technologies to meet the ever-increasing demands. There is no universally accepted definition for personal communications services (PCS). PCS is a vague term that expresses the service capabilities of all types of personal communications [1]. Personal communication services provide personalized voice, data, image, and video communications services anywhere, anytime, with anybody. With PCS, we can communicate from person to person, regardless of where we are physically located. PCS makes communication independent not only of distance and location, but also of time. As a class of services, PCS embraces a wide range of capabilities, but its fundamental benefit is the ability to communicate from virtually anywhere to virtually anywhere else. The realization of personal communications services makes some requirements necessary on various types of networks, in particular, mobility and interworking.

From the technical perspective, PCS is the U.S. Federal Communications Commission (FCC) term used to describe a set of digital cellular technologies deployed in the U.S. Also referred to as digital cellular, PCS works over CDMA (also called IS-95), GSM, and North American TDMA (also called IS-136) air interfaces. PCS still belongs to 2G mobile communications technology and includes enhanced personal communications services such as SMS text messaging or caller ID. However, PCS is not a totally new 2G technology. Three of the most important features of PCS systems are: 1) completely digital; 2) operating at the 1900MHz frequency range (unlike other cellular systems that operate in the 800MHz frequency range); 3) they can be used internationally.

## 2. Technological Evolution for Personal Communications

To understand PCS, we first review the history of technological development in personal communications.

### Mobile Radio

Mobile radio is the earliest system for personal communications. It was proprietary and costly. It could be used within a certain region. The first recorded mobile radio services that provided interconnection to the switched telephone network was in 1946 when the FCC allocated six radio channels for the first public correspondence system in Saint Louis. During the 1950's and 1960's the service evolved into manual Mobile Telephone Service (MTS) where mobile units called into operators who manually placed the calls. The modulation type was narrow-band FM and a single high-power base station provided coverage of some 20-30-mi (30-50 km) radius to several hundred mobiles per 20-30 KHz-wide radio channel. In 1964, a new service was introduced called Improved Mobile Telephone Service (IMTS). IMTS replaced MTS and allowed a mobile subscriber to directly dial a telephone number. In IMTS, on the order of 8 channels per major city were available with an automatic channel selection mechanism (Stuart, 1994).

## Cellular Telephone

It was not until 1983 that today's analog cellular services were introduced to the U.S. on a commercial basis. However, it is the crucial step towards PCS. The first cellular systems were built in Chicago and Baltimore and within a few years were serving tens of thousands of subscribers. The cellular analog standard used in North America was called Advanced Mobile Phone Service (AMPS). AMPS represents the first-generation wireless communication networks. It allocates frequency ranges within the 800 and 900 MHz spectrum to cellular telephone. Each service provider can use half of the 824-849 MHz range for signal reception and half of the 869-894 MHz range for signal transmission. The bands are divided into 30 KHz sub-bands, called channels. The division of the spectrum into sub-band channels is achieved by using Frequency Division Multiple Access (FDMA). As a user moves out of a cell's area into an adjacent cell, the user begins to pick up the new cell's signals without any noticeable transition. The analog service of AMPS had been updated with digital cellular service by adding to FDMA a further subdivision of each channel using Time Division Multiple Access (TDMA). This service is known as digital AMPS (D-AMPS), which is a 2G technology.

## Cordless Telephone

It is a telephone with a wireless handset which communicates with a base station connected to a fixed telephone landline via radio waves. It can only be operated close to (typically less than 100 metres of) its base station. Cordless telephone is an attempt on location-independent communication with limited useful range. With it, people can keep in touch out in the garden, up in the attic, and over at the next-door neighbour's. Modern cordless telephone standards, like Personal Handy-phone System (PHS) and Digital Enhanced Cordless Telecommunications (DECT), have blended the once clear-cut line between cordless and mobile telephones by supporting cell handover, various advanced features like data transfer and even, on a limited scale, international roaming.

## Cellular Data

2G is based on circuit-switched technology where each call requires its own cell channel, which makes transmission of data quite slow. The representative technology of 2G is GSM (Global System for Mobile communications). Voice is digitally encoded and transmitted through the GSM network as a digital stream. A variety of data services is offered and the most popular one is SMS (Short Message Service). GSM was initially deployed in Europe and soon became popular worldwide. GPRS (General Packet Radio Service) is a representative 2.5G network that supports low rate mobile data communications. It uses a packet-mode technique to transfer data and signaling in a cost-efficient manner over GSM radio networks and also optimizes the use of radio and network resources. 2.5G is a transitional technology between 2G and 3G. 3G mobile communication technology is also called IMT-2000 by International Telecommunication Union (ITU). 3G networks will provide voice communication quality on a par with telephone networks, with minimal interference and noise, and support diverse multimedia content. Using 3G terminals, users can access a wide range of telecommunication services supported by the fixed telecommunication networks (e.g., PSTN/ISDN/IP), and to other services which are specific to mobile users.

## Satellite Communications

True personal communication must be ubiquitous, meaning that two-way voice and data should be available anywhere in the world, no matter how remote or underdeveloped that location [2]. Such services have become possible with the aid of low earth-orbit (LEO) satellite network. These satellites move around the earth with orbits low enough to permit portable PCS telephones and data terminals to communicate through one or more satellites to a regional gateway earth station, which can provide a connection into the public switched telephone network.

## PCN

Expansion from cellular to personal communications services occurred at a quickening pace worldwide. Personal communications networks (PCN's) provide mobile two-way and mass-market communication services, the most advanced offering of the PCS area. The terms PCN and PCS are often used interchangeably. PCS refers to a service which may not embody all of the PCN concepts, but is more personalized (i.e., lightweight terminal, better performance, more flexibility and user options, etc.) than cellular-radio. PCN refers to a concept where a person can use a single communicator anywhere in the world [3]. The idea behind PCN is to make communications truly personal and ubiquitous, so that the users can call each other, no matter what the location of the user.

## Internetwork

An Internetwork functions as a single large network, which is a collection of individual networks connected by intermediate networking devices. A local area network (LAN) enables multiple users in a relatively small geographical area to exchange files and messages, as well as access shared resources such as file servers and printers. Wide area networks (WAN's) interconnect LANs with geographically dispersed users to create connectivity. Internet, the largest Internetwork, is a global WAN and interconnects various data communication networks. Internet is mainly designed and used for data communications. Nowadays, with the advance in technologies, more and more people conduct voice communications through the

Internet. Compared to the cellular networks, the Internet can provide cheap voice communications with competitive quality.

With these in place, the ever-quickening pace of technological advances has made available a wide variety of personal communication services, universally and ubiquitously.

# 3. Key Issues in PCS

## 3.1. Spectrum Allocation

The 1992 World Administrative Radio Conference (WARC92) of the ITU resulted in a worldwide allocation for mobile services in the 1.7 to 2.69 GHz band [4]. This brought all three regions of the world into conformity under the Future Public Land Mobile Telecommunications Systems (FPLMTS, now IMT2000), which are systems capable of providing a wide range of services including personal communications with regional or international roaming. The FPLMTS concept incorporates both terrestrial and satellite-delivered PCS services. The conference identified the sub-bands 1885 to 2025 MHz and 2110 to 2200 MHz for implementation of terrestrial PCS components on a worldwide basis. The conference also allocated spectrum for LEO satellite services that can provide PCS-type services to remote areas. For LEO systems operating below 1 GHz, a primary global allocation in the 149.9 to 150.05 MHz band was made and secondary allocations at 312 to 315 MHz and 387 to 390 MHz were made. For LEO systems above 1 GHz, primary allocation in the 1610 to 1625.5 MHz band (Earth to space) paired with the 2483.5 to 2520 MHz band (space to Earth) and a secondary allocation at 1613.8 to 1626.5 MHz were made.

The spectrum allocated to PCS is divided into three major categories: broadband, narrowband, and unlicensed. The FCC controlled the spectrum allocation for broadband PCS in the U.S., and defined rules for auctioning the spectrum to potential PCS service providers. The most challenging and controversial decision confronting the FCC was to determine a frequency allocation for PCS that takes into account the competing demands of existing licenses for scarce spectrum. Fortunately, these new rulings received a lot support and praise by the industry [5]. Broadband PCS operates in the 1850-1910 MHz and 1930-1990 MHz bands. Narrowband PCS operates in the 901-902 MHz, 930-931 MHz, and 940-941 MHz bands. For unlicensed PCS services, a 20 MHz spectrum in 1910–1930 MHz band was allocated.

Since the spectrum resource is not unlimited, one of the most fundamental issues concerns overcrowding on the radio frequency spectrum. Efficiently sharing the spectrum resource is of paramount importance in wireless communication systems, in particular in personal communications where large numbers of wireless subscribers need to be served [6]. There is always a desire to promote increased flexibility, innovation, and efficient usage of the spectrum resource. The frequencies most favored are below 1 GHz because they diffract around objects better, but this limited bandwidth could not satisfy the demand without reusing the band many times [7]. The simplest form of reuse is geographic separation. In addition, one of the most promising alternatives to spectrum reallocation is to use the current spectrum more efficiently. By using multiple access, digital technology has improved frequency efficiency and decreased costs to the point that personal communications appeal to people around the world. Multiple access refers to the simultaneous transmission by numerous users to or through a common receiving point. The three types of multiple access presently used with personal communications are code-division, frequency-division, and time-division multiple access, i.e., CDMA, FDMA, and TDMA.

## 3.2. Mobility

PCS supports the mobility of users both as they roam from system to system between phone calls, and supports handoffs between base stations within and between adjacent systems [8]. The functions of mobility management include: handoff, location management, and registration for service while roaming. The functions control the location of PCS end users, the use of terminal equipment, and the availability of PCS anytime, anywhere. Three types of mobility have to be considered in PCS [1]: terminal mobility, personal mobility, and service mobility (also called service portability). According to the definition given by the T1P1 Committee of the American Telecommunications Standards Institute (ATSI), PCS must contain the following three functionalities:

1. *Terminal Mobility* – From the user's viewpoint, it is the ability of a mobile and wireless terminal to access communication services from different locations while in motion. From the service provider's viewpoint, it is the ability of the network to identify, locate, and track the mobile terminals.
2. *Personal Mobility* – Personal mobility also has two layers of meaning. From the user's viewpoint, it is the ability of a user to access communication services based on a personal identification code on any terminal irrespective of wireless or wireline connection. From the service provider's viewpoint, it is the ability of the network to locate the terminal associated with the user and provide those services according to the user's service profile. Once the terminal associated with one user is located, the network needs to do addressing, routing, and charging about the user's calls.
3. *Service Profile Management* – It refers to the ability of a user to access and manipulate the user's service profile. Service profile management may be realized by the database system, which controls the access to and handling of data. The consistency of information in the service profile can be guaranteed by the service profile management functions.
4. *Service Mobility* – It can be seen as a combination of terminal mobility and personal mobility, is related to service profile management. Service mobility refers to the network capability to provide subscribed services (e.g., a user's individual service profile at a user-designated terminal or location) and identify the user at any access location by supporting terminal and/or personal mobility.

## 3.3. Standardization Efforts

PCS is based on digital architecture, generally using TDMA or CDMA protocols. A remarkable technical characteristic of PCS is its high capacity and spectral efficiency. International standards were developed to meet the global standardization demand for PCS equipments and systems. For specifying the functionalities and standards of PCS, the standardization organizations include ITU, ETSI (European Telecommunications Standards Institute), TIA (Telecommunications Industry Association, affiliated with the Electronic Industries Association), and the Committee T1. A joint technical committee between T1P1 and TR46 subcommittees has coordinated the joint work on the PCS standards between T1 and TIA. The joint technical committee has defined methodology and selection criteria in selecting appropriate radio interface technology.

In U.S., the T1P1.2 and T1P1.3 have defined high-level requirements for PCS standardization and documented these in technical reports. The T1P1.2 developed a reference model for PCS and identified six different configurations as potential ways of implementing the reference model [9]. T1P1 also has played a significant role in defining personal mobility, also known as UPT (Universal Personal Telecommunications). TR-46 subcommittee of TIA specified a reference model from the perspective of a cellular service provider [10]. Other organizations such as PCIA (Personal Communications Industry Association) also have specified PCS reference models and proposed implementation options [11]. PCS data standards were investigated by the joint technical committee of Committee T1 and the TIA, the ITU–T (ITU–Telecommunications standardization sector), and others.

# 4. System Architecture

## 4.1. Heterogeneous PCS (HPCS)

PCS may appear in many forms and consist of a plethora of systems that address cordless phone, cellular, vehicular, and a variety of other services. Two of the most popular technologies used in PCS are cellular telephony and cordless telephony. Cellular systems can be AMPS, GSM, ADC (American Digital Cellular or IS-54, and the newer version, IS-136), and DCS1800 (Digital Communication System at 1800 MHz), et al. Among cordless telecommunication systems exist the CT2 (Cordless Telephone 2), DECT, PACS (Personal Access Communications Systems), and PHS. Integration of different PCS systems was proposed, particularly integration of cellular and cordless systems to provide better services than any individual system. The integration of these different systems is referred to as “heterogeneous PCS (HPCS)” [12].

In HPCS, the service areas of different individual PCS systems may overlap or not. If there is an overlapping, the system typically operates at different frequency bands, and the integration can increase the system capacity. If there is no overlapping, obviously the integration of these systems can extend the coverage of the service area. For example, a simple HPCS is formed by integrating a cellular system and a cordless telecommunication system. In such a simple HPCS, from the perspective of the cellular system, the quality of circuits is improved; and from the perspective of the cordless system, higher user mobility is supported.

A basic requirement of HPCS is downward compatibility. In HPCS, users will receive services from multiple PCS systems since hey have been integrated. At the same time, the original users of the individual PCS systems will still receive services from their systems without being affected by HPCS. Depending on the network and radio technologies, in [12], three types of integration are considered: SRSN (Similar Radio technology, Same Network technology), DRSN (Different Radio technology, Same Network technology), DRDN (Different Radio technology, Different Network technology). Different integration type has significantly different effect on the implementation of HPCS. One obvious issue is handover between different systems. Another important issue is roaming management which involves three aspects (registration, call delivery, and handset identity). Both issues were deeply investigated in implementations of HPCS.

### 4.2. Distributed Network Architecture

Centralized cellular network architectures are likely to be unsuitable for management of the anticipated PCS demand, including the associated signaling arising. So, distributed network architecture to support PCS demand should be designed to incur low network signaling overhead. In [13], a distributed microcellular architecture based on the IEEE 802.6 metropolitan area network (MAN) was proposed to facilitate PCS deployment. The MAN supports both voice and data traffic using a dual bus architecture. The Mobile Control Center (MCC) on the MAN has the responsibility of managing the mobile aspects of calls. The Signaling Terminal (ST) on the MAN is to manage the fixed parts of all calls. Fixed and wireless terminals connected to LANs and PBXs provide PCS coverage within buildings. To provide a contiguous coverage in public areas, sets of base stations controlling microcells are interconnected to MANs via heterogeneous bridges, as in figure 1. A MAN-oriented microcellular system architecture can reduce traffic congestion by dynamic sharing of data link capacity and by partitioning call control functions to a distributed switch.

In [14], another distributed architecture called Wireless Distributed Call Processing Architecture (WDCPA) was proposed. In WDCPA, a new network element named the user signaling server is added, which provides proxy services on behalf of mobile users and helps increase signaling efficiency. In addition, with the advent of multimedia services and multi-connection mobile computing applications (e.g., Internet multimedia multicast), multi-connection calls become more and more important. To support multi-connection services, WDCPA separates connection control from call control in its architecture. WDCPA also distributes call processing functions from switching entities. Thus, more efficient control procedures are allowed to be developed since the processing for a control function can be placed closer to the data needed to perform the function. In WDCPA, the wired network infrastructure is assumed to be B-ISDN standards in order to support multimedia and other QoS-dependent services. However, the mobility management algorithms and structure of WDCPA do not depend on the wired infrastructure.

### 4.3. Intelligent Network

Intelligent network (IN) is an architectural concept of telecommunication networks, which is formally defined by ITU-T in 1992. It provides a flexible and open architecture to improve service implementation and provisioning in a more cost-effective manner than traditional concepts [1]. To provide a ubiquitous PCS, it is essential to integrate different telecommunication networks and systems. In fixed networks, intelligent network has been introduced to facilitate the development of new services. IN was also used to integrate mobility in fixed networks. In mobile cellular networks, although mobility management has already existed as a component, it is desirable to introduce the IN concept to increase the flexibility of such networks, allowing an improved services provision. With the convergence of fixed networks and mobile networks becoming more and more popular, the IN concept can be utilized to provide necessary networking functions for their integration.

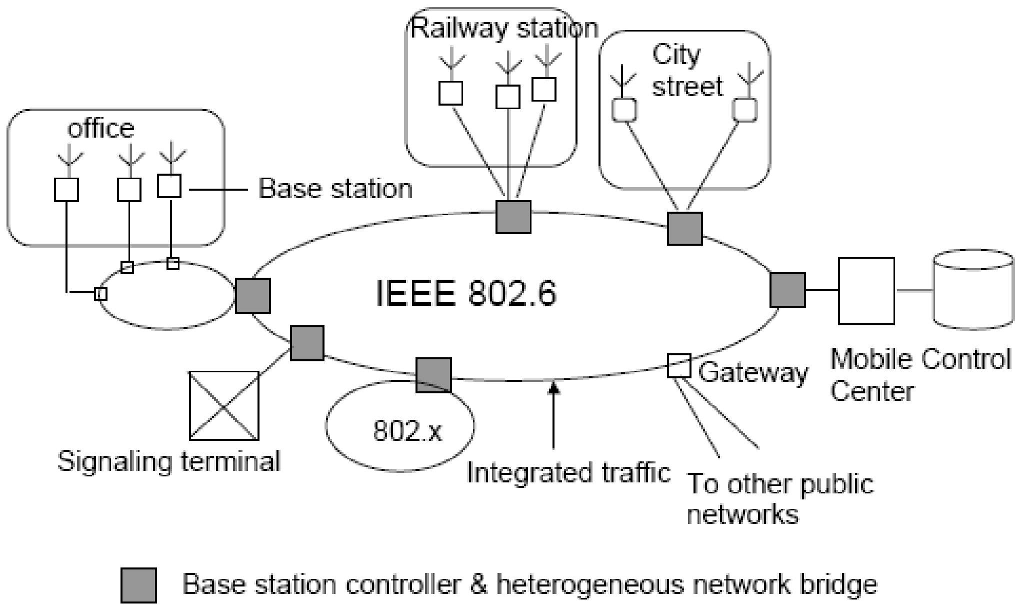


Figure 1. A distributed PCS network architecture based on IEEE 802.6 MAN.

There are two types of INs in the world. One has been developed by ITU and called IN Capacity Set-x (CS-x). This is an international IN standard. The other is the Advanced Intelligent Network (AIN), which has been standardized by Bellcore in the U.S. We focus on the international IN standard. ITU-T has realized the Recommendations concerning IN by three phases: Capacity Set-1 (CS-1), Capacity Set-2, Capacity Set-3. CS-1, the first phase of IN systems, defines a complete architecture including the architectural view, state machines, physical implementation and protocols. It is the formal indication that the IN was produced. CS-2 includes many new capabilities over CS–1. It has addressed key issues such as B-ISDN, mobility, and multimedia services. CS-2 also makes standards to cover the service creation, service management functions. CS-3 is a superset of CS-2, thus all parameters supported in CS-2 are also supported in CS-3. CS-3 supports IMT-2000 for the realization of mobile multimedia service, and provides the standards to combine IN, B-ISDN, and Telecommunications Management Network (TMN). Summarizing, we can relate broadly the CS-1 to PSTN and ISDN, the CS-2 to B-ISDN, and the CS-3 to the fixed and mobile networks.

The IN Conceptual Model (INCM) specifies the framework to describe and design IN architectures. The INCM provides four views of a telecommunication network through which a given service is modelled. These views correspond to four planes [15]. In the following, we describe them one by one.

The service plane (SP) presents to end users an abstract view of the services provided by an IN-based network. In this plane, an IN service is described by a set of service features (SF's).

The global functional plane (GFP) provides a view to design services. SFs are realized by components called service-independent building blocks (SIB's). Thus, an IN service is built by a set of SIBs which represents the service logic (SL) used to realize the service.

The distributed functional plane (DFP) defines functional entities (FE's) to characterize the functional aspect of the network. These encompass actions called functional entity actions (FEA's) invoked by the SIBs. The IN FEs include call control agent function (CCAF), service creation environment function (SCEF), service management access function (SMAF), service switching function/call control function (SSF/CCF), service management function (SMF), service control function (SCF), service data function (SDF), and specialized resource function (SRF). IN Application Protocol (INAP) is the protocol used by the FE to communicate with each other. Three categories of functions are identified in the DFP: the *access functions* – invoked during the access of a given service and for the connection between users; the *intelligence functions* –used to perform a given service; and the *management functions* – dedicated to the service creation and service management.

The physical plane (PP) shows how the different FE of the DFP are mapped onto physical entities (PE). Physical entities communicate with each other through a communication protocol. The IN PE include service switching point (SSP), service control point (SCP), service management point (SMP), and intelligent peripheral (IP). Among them, SSP, SCP, and IP are in conjunction responsible for the real-time execution and control of the end-user services. The SSP capabilities are defined in terms of trigger check points (TCP's), and the SCP and IP capabilities in terms of FEAs.

The application of IN to fixed and mobile networks is very convenient to realize PCS. PCS was also regarded as a leading driver for deployment of intelligent network. Modelling PCS in IN means that services are specified with entities associated to INCM in each of the four planes. In the SP, PCS is defined with pre-existent SFs, which are usable to specify several services. In the GFP, PCS is built with the description of a sequence of SIB to generate their SL. In the DFP, PCS is decomposed into FE distributed in an IN environment. In the PP, PE contain the FE of DFP. Figure 2 describes the IN functional architecture for PCS.

In [16], it proposed to outline the IN requirements for implementing PCS in the following steps.

1. Identify a set of PCS feature requirements needed by end users.
2. Identify the specific TCPs and FEAs required to implement the PCS features.
3. The final result is a subset of IN capabilities that can be rationalized against a specific service. As such, these capabilities could be used as the starting point for an economic analysis of IN implementation cost versus service worth.

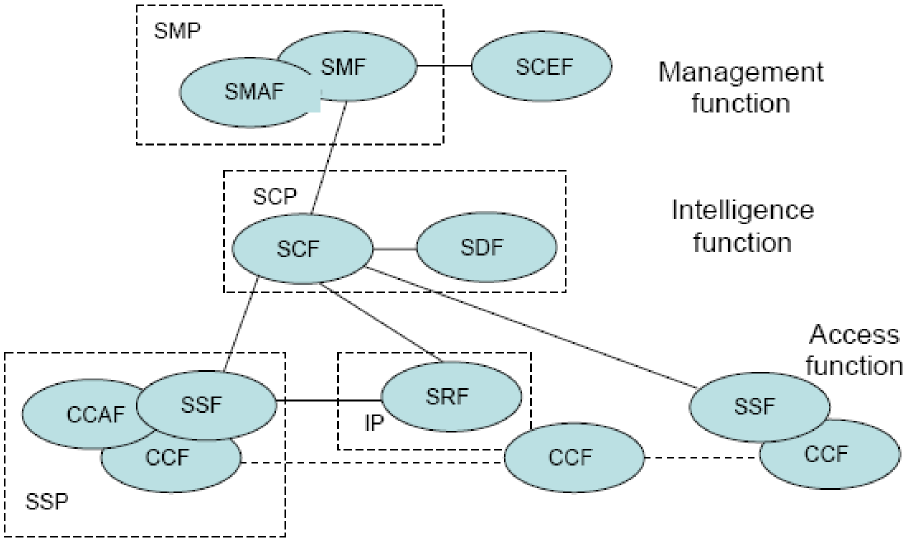


Figure 2. IN functional architecture for PCS.

The industry also used IN to deploy PCS in order to support interworking and interoperability. PCS wireless system needs to accommodate mobility of all its intended users. To support the user mobility, the cellular and PCS systems need to interoperate to maintain a call. The different types of wireless systems also utilize the capabilities of the IN to provide seamless roaming [17]. Interoperability between service providers will minimize the user interface inconsistencies that may be caused by inherently different system implementations. For example, MSC-based systems utilize IN elements (HLR and VLR) along with a mobile switching center (MSC) to provide high-mobility PCS capability where service providers wish to operate and manage their own systems. In Class 5 switch-based systems, use of standard wireline interfaces and capabilities allows various PCS network elements to coexist. This architecture incorporates major IN elements, and provides the evolutionary path to migrate the PCS system to both low- and high-mobility PCS traffic [18].

The IN intersystem protocols are IS-41 MAP (defined by EIA/TIA IS-41C, MAP stands for mobile application part), PCS 1900 MAP (PCS 1900 is a derivative of GSM), and advanced intelligent network (AIN). Interworking and interoperability between IS-41 MAP and PCS 1900 MAP systems is a key issue in ensuring that seamless roaming is provided to mobile users. These intersystem protocols play a key role in interconnecting various network elements to the MSC or SCP to a Class 5 switch. By these protocols, diverse networks are interconnected to offer ubiquitous service, universal accessibility, and seamless roaming.

## 5. Application and Deployment

PCS has been widely used in the world. In this section, we introduce its applications and deployment status in some countries distributed in Asia, Europe, and North America. Since PCS refers to a 2G mobile communication technology, its development and deployment began from the mid-term of 1990’s.

We first consider a very simple application of PCS. For example, John needs to make a business trip from his home office in Hong Kong to Beijing, China. John brings a mobile phone which has the capability of global roaming. Obviously, he would be willing to pay overseas long distance charges to receive only some important calls. With a personal setting supported by the capabilities of PCS, John could control which calls should be automatically redirected to his office in Hong Kong, which calls should go to a voice mail system, and which calls should be forwarded to Beijing. With such PCS capabilities, people could truly personalize the telephone network for their individual communication requirements.

PCS technology appeared ideally for special events like the large-scale conventions, national sports meetings even Olympic Games. In 1984, California hosted the Los Angeles Olympic Summer Game, the Super Bowl, and baseball's All Star Game within half a year. In each case, Pacific Bell (Pacific Telesis Group's telephone operating company in California) had to create large numbers of wireline communications links just before the event, and then take them down or redeploy them after the event was over. With the development of mobile and wireless communication technology, such messy situations have been significantly changed. Telecommunication service providers could conceivably use PCS technology to meet the requirements of these special-events more effectively and more economically than is possible with wireline technology alone. The 2008 Olympic Summer Game will be held in Beijing, China. In China, several major telecommunication companies are developing 3G networks to provide high-quality wireless multimedia communication services for it.

In Asia, we use Korea as an example to describe the deployment status of PCS. In 1994, the Korea government officially announced its plan to introduce PCS into the market. Since then, the technological development and commercialization of PCS were expedited as a viable competitor against the cellular industry. Korea Telecom (KT), Korea's main telephone operator, also began to develop PCS networks and proposed KT-PCS, which was supposed to be the basis for the next generation of wireless communications. In the following, we briefly introduce KT-PCS.

Since KT had built a national PSTN, it is necessary and beneficial to make full use of the facilities of PSTN to realize an efficient PCS network. Therefore, KT-PCS was integrated with the PSTN network. Furthermore, the capabilities of ISDN and intelligent network was fully employed to establish a reliable and economical network. Initially, the KT-PCS consisted of personal communication exchange (PCX), PCS base station (PBS), PCS base station controller (PBC), radio operation and maintenance system (ROMS), and home location register (HLR) connected to PCX through a SS7 signaling network [19]. PCX is the PCS switching system and handles PSTN switch functions and MSC functions such as mobility management. When the number of PCXs expands beyond a certain level, the PCS network was integrated into the PSTN by interconnecting PCXs through PSTN's toll or tandem switching systems. The HLR is the centralized database system to which all the PCXs are connected through a SS7 network. For the air interface, KT-PCS adopted upbanded GSM.

KT-PCS was expected to cover the whole South Korean territory and provide communication services seamlessly to KT-PCS subscribers. KT-PCS differentiated itself from regular cellular services by emphasizing on the advanced services with low service charge and special services for business applications. The advanced services include personal number (PN) service, SMS, voice/fax mail, et al. In addition, both interoperability with various other cellular networks and interaction with ISDN and IN are also important and necessary functionalities in KT-PCS. In 1996, the Korea government decided that CDMA technology would be used for digital cellular. In response to this policy change, KT-PCS was also required to be able to operate with a CDMA cellular network.

We also briefly introduce the PCS application and deployment in Hong Kong, another Asia-Pacific region. In August 1996, the Hong Kong government awarded six new PCS licenses in the 1.8-2 GHz band to six telecommunication companies after extensive discussions. Each of them got two blocks of 5 MHz of spectrum, with additional capacity to be allocated later according to demonstrated need. At that time, the capacity of the spectrum allocated for the PCS is estimated to be 1.2 million [20]. Obviously, the later requirement on personal communications is far beyond the original imagination.

In Europe, we demonstrate the deployment of PCS in U.K. Before the operation of GSM system even begun, the U.K. government had licensed three operators to provide personal communications services, using a spectrum allocation of 2×75 MHz at around 1800 MHz. After some discussions, the operators settled on DCS1800, a system firmly based on GSM technology. Compared to a GSM network, the available spectrum was increased in DCS1800. This gave the operator greater flexibility in frequency planning and capability to serve a larger customer base. Vodafone and Cellnet are two primary telecommunication companies in the U.K. They launched the cellular service at the same time early in 1985. Vodafone was the first network to provide a full GSM service in the UK. At the Communications 91 exhibition in Geneva, Vodafone also announced plans for a PCS service as a microcellular network (MCN). Since then the service has been launched under the name MetroDigital [21]. The MCN service is available in any significant built-up area. In addition, because the GSM network can provide almost nationwide coverage, the GSM and MCN services are, therefore, complementary.

In North America, both GSM and IS-41 were implemented for PCS. The FCC has allocated a range of spectrum for licensed and unlicensed PCS. IS-41 were intersystem standards that support intersystem roaming and automatic registration capabilities. However, there were six different air interfaces planned for PCS using two different MAPs. Just like what we have mentioned before, the interworking and interoperability (I&I) caused by the multiplicity of standards and systems were addressed. For the privacy and authentication related to I&I, three security mechanisms were proposed for PCS systems including the standard IS-41-based authentication mechanism, the DCS1900-based authentication mechanism using secret key with authentication triplets, and a public key system proposed for the PACS air interface. In addition, TIA proposed HLR-IIF, a dual mode HLR solution for I&I functionality between the IS-41 and the DCS1900 MAPs to support privacy, authentication, and service interworking. Certainly, the HLR-IIF would bring extra signaling load to the network. By the evaluation conducted in [22], the signaling load on the network increases 50 percent (in the case of I&I between DCS1900 and IS-41 systems) and 100 percent (in the case of I&I between IS-41 and DCS1900 systems) with respect to I&I between two similar IS-41 systems.

## 6. CONCLUSION

PCS is a set of capabilities that allows some combination of terminal mobility, personal mobility, and service profile management. That is, it emphasizes person-to-person rather than traditional point-to-point communication. The services provided by PCS are more convenient, ubiquitous, and versatile than the public has ever received. Technically, cellular systems in the U.S. operate in the 824-849 MHz frequency bands; PCS operates in the 1850-1990 MHz bands. A typical PCS network would use uniform microcells with a high degree of frequency reuse.

PCS has two outstanding characteristics: support mobile users, and support multimedia communication. The "personal" in PCS also distinguishes this service from cellular by emphasizing that, PCS is designed for greater user mobility. It generally requires more cell transmitters for coverage, but has the advantage of fewer blind spots. Ubiquitous PCS can be implemented only by integrating the wireless and wireline systems on the basis of intelligent network. Furthermore, advanced PCS system architectures must account for the increasing demand for Internet access and other private data service requirements.

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