Cellular digital packet data

Taking over when no one's talking

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Cellular Digital Packet Data (CDPD) offers on-the-go users access to a low-cost, widespread, wireless data network. CDPD can be overlaid on existing analog cellular systems, and share their infrastructure equipment on a non-interfering basis.

Basically, CDPD transmits packet data over idle cellular channels. It autonomously switches to another channel when the current channel is about to be assigned for voice usage. CDPD does not communicate with the underlining cellular network. However, CDPD does use its knowledge about the channel assignment algorithm of the cellular cell to predict the channels available for CDPD use.

CDPD may serve as the wireless extension to other data networks (e.g., Internet) or public switched telephone networks. It supports connectionless network services which have packets called network protocol data units (NPDU). Every packet is routed individually based on the destination address of the packet and knowledge of the current network topology. Initially, CDPD provides two connectionless network services: the standard open systems interconnection connectionless network protocol and the Internet protocol.

The architecture

There are two basic classes of network entities in the CDPD network: end systems and intermediate systems. For our purpose, we only consider the mobile parts of the network; that is, we only will consider the mobile end systems and the mobile data-intermediate systems. Figure 1 illustrates the CDPD network reference model.

Mobile end system. A CDPD user communicates with the CDPD network by using the mobile end system. The physical location of the mobile end systems may change from time to time, but continuous network access is still maintained. A mobile end system may be a credit card verification unit installed in a taxi, a personal communicator or a personal data assistant, or a CDPD modem for a personal computer, a palmtop or a laptop. (The laptop may incorporate a cellular transceiver and rechargeable batteries in a palm-sized, serially-connected unit to a personal computer.)

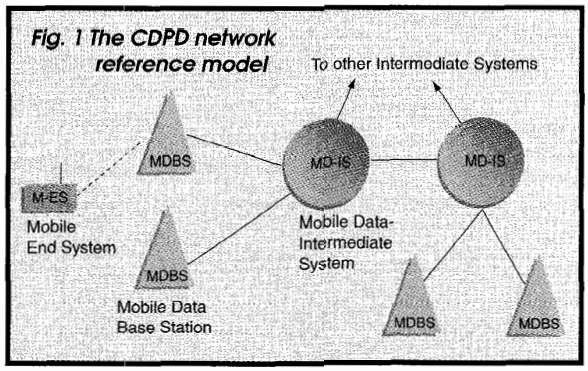

Fig. 1 The CDPD network reference model

The mobile end system has three parts: the *subscriber unit*, used to access the radio interface; the *subscriber identity module*, which contains information to identify a subscriber, and the *mobile application subsystem*, which provides the mobile end system application functionality. It can be a personal computer or a simple data gathering/telemetric tool.

Mobile data base station. The mobile data base station is responsible for detailed control of the radio interface such as radio channel allocation, interoperation with cellular voice channel usage and radio media access control. In order to share radio resources with the cellular system, mobile data base stations are expected to be colocated with the voice equipment that provide cellular telephone service. Furthermore, mobile data base stations may share cellular equipment (such as antennas for transmitters and receivers) to communicate with the mobile end systems. Mobile end systems can only communicate with the outside world through mobile data base stations. Also, there is no direct communication path between mobile end systems. Because of the short synchronization delay (i.e., two bit delay) between the mobile data base station and the mobile end system, the radius of a CDPD is typically limited to less than 10 miles.

Mobile data-intermediate system. A mobile data-intermediate system connects to several mobile data base stations via wire links (e.g., multiple digital signal 0 trunks) or microwaves. The mobile data-intermediate system consists of a frame relay switch, a packet router and a workstation. It receives data from one correspondent network entity and forwards it to another correspondent network entity. The mobile data-intermediate system supports user mobility by operating a CDPD-specific mobile network location protocol to exchange location information of CDPD users.

A mobile end system communicates with the corresponding mobile data base station by a 19.2 kb/s raw duplex wireless link. (This is referred to as a CDPD channel stream.) A CDPD channel stream can be accessed by several mobile end systems.

CDPD channel streams use idle cellular radios to transmit data to and from mobile end systems. However, CDPD systems are designed to use idle cellular capacity without direct communication with the cellular system. Also, a strict requirement is that

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CDPD transmissions must not interfere with cellular voice calls. We will describe how this goal is achieved in the following sections.

Air interface and protocols

The link from the mobile data base station to the mobile end system is called the *forward link*. The link from the mobile end system to the mobile data base station is called the *reverse link*. The raw data rate on both links is 19.2 kb/s. The mobile data-intermediate system queues all frames, and sends them to the corresponding mobile data base station for transmission on the forward link. The mobile data base station broadcasts the frames in its radio coverage area. Only mobile end systems that have valid network entity identifiers can decode the data received. It is clear that the transmission on the forward link is contentionless.

CDPD follows the traditional slotted, non-persistent digital sense multiple access protocol for the reverse link access. The protocol works as follows. The mobile data base station broadcasts (on the forward link) the availability of the reverse link by the idle/busy control flags. If there are no transmissions on the reverse channel, the mobile data base station sets the control flag on "idle."

Upon detecting the idle status, a mobile end system may transmit the data on the reverse link. If the mobile end system detects the "busy" status, it waits for a random period of time, and rechecks the status of the control flag. Two mobile end systems may detect the "idle" status and try to access the reverse link at the same time. In this case, a collision occurs and the mobile end systems follow an exponential back off procedure for retransmission.

A mobile end system may repeatedly transmit long bursts. To prevent this channel hogging situation, a minimum time period is defined between two bursts of a mobile end system. This ensures that other mobile end systems have the chance to access the reverse link.

A sleep mode is provided in CDPD to allow an idle mobile end system to shut off power for a defined period. To "wake up" the mobile end system, the mobile data-intermediate system periodically broadcasts a notification message that lists mobile end systems that are recipients of the frames it has in queue.

The mobile end system periodically activates its receiver to listen to the broadcast notification message. If it hears its name, the mobile end system leaves the sleep mode by sending a message to the mobile data-intermediate system. With this mechanism, the battery life of the mobile end system can last longer. (Twelve hour battery life using the CDPD power-saving mode has been reported in commercial products.)

Radio resource allocation

During the monitoring phase, the mobile data base station can determine the availability of channels in two ways. If a communication link between the cellular system and the CDPD system exists, then the information of the voice channel usage can be obtained directly from the cellular system. If such a communication link does not exist, then the mobile data base station detects the channel usage through the cellular transmit path by using a forward power monitor called a *sniffer*. Since every cell may contain as many as 60 voice channels, it is critical that the mobile data base station finds the available channels in real-time.

With the channel monitoring mechanism, the mobile data base station should be able to change channels before a voice assignment is made on the current CDPD channel. This action should be completed in 40 msec. When the mobile data base station detects that the CDPD channel is about to be assigned to a voice call, it performs an emergency or *forced hop* by switching the channel without informing its mobile end systems. When a mobile end system loses contact with the forward link, it searches the "likely hopped" channel list (broadcasted by the mobile data base station) to reestablish the radio link.

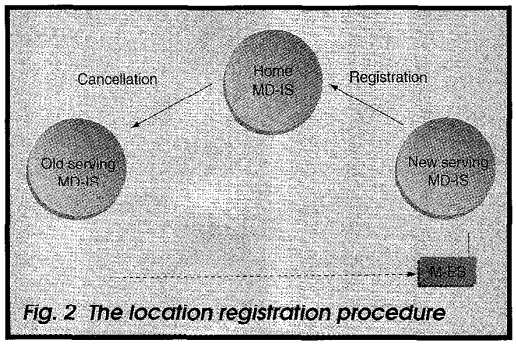

Fig. 2 The location registration procedure

With channel sniffing and channel hopping, CDPD allows mobile end systems to use idle voice channels without interrupting the cellular system. A mobile data base station periodically scans the channels within its radio coverage area and generates a candidate list of available channels for CDPD traffic. This list is then forwarded to the mobile data-intermediate system. The mobile data-intermediate system collects all channel lists from the associated mobile data base stations, and determines the CDPD channel streams based on its knowledge of the voice channel allocation algorithm.

The mobile data base station may periodically perform channel switching (referred to as *timed* or *planned hop*) to avoid channel sealing or channel stealing. When the cellular system notices interference on a channel, the channel is sealed and becomes unavailable to a voice user. Since the cellular system cannot recognize CDPD, it may seal a channel used by CDPD. Then the channel cannot be used by the cellular users. If so, CDPD is said to have stolen the channel from the cellular network. This violates the rule that CDPD should not affect the voice system.

To avoid the sealing of a CDPD channel, the mobile data base station uses a timed hop to switch a CDPD channel stream periodically. (The hop period is on the order of 10 seconds.) In a timed hop, the mobile data base station broadcasts a control message to all mobile end systems using the channel, and instructs them to move to a new channel (if any). Channel hopping may not be performed if dedicated channels are assigned for CDPD use.

When a mobile end system in communication moves from one cell to another, a radio link transfer process is required to reconnect the mobile end system in the new cell. The CDPD transfer process is controlled by the mobile end system.

The mobile end system monitors the radio link quality. If the quality falls below the defined thresholds for the radio signal strength and error rates, the mobile end system initiates the link transfer process by searching a better quality channel. (A list of available channels are broadcast by the mobile data base stations.)

The mobile end system tunes to the new channel and informs the new mobile data base station that it has entered the cell. The new mobile data-

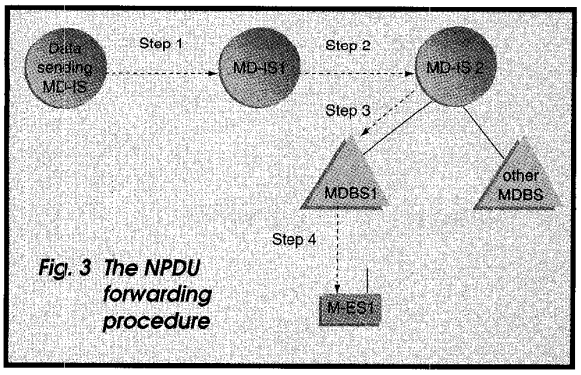

Fig. 3 The NPDU forwarding procedure

intermediate system updates its registration directory so that future data for the mobile end system are directed to the current cell. If the old and the new mobile data base stations connect to different mobile data-intermediate systems, the transport layer retransmission is required to reestablish the end-to-end connection.

Roaming management

The CDPD roaming management is achieved by two functions: the mobile home function and the mobile serving function. A mobile end system is identified by a distinct network entity identifier. Every network entity identifier is associated with a home mobile data-intermediate system. The home mobile data-intermediate system maintains a location directory to record the address of the current serving mobile data-intermediate system for each of its home mobile end systems. (This procedure is referred to as the location directory service.)

The mobile end system may roam away from its home mobile data-intermediate system and visit another mobile data-intermediate system. The visited mobile data-intermediate system maintains a registration directory to keep track of all visiting mobile end systems. (This procedure is referred to as the registration directory service in the mobile home function.)

Location registration. From the channel stream, a mobile end system identifies its location (the address of the serving mobile data-intermediate system). When the mobile end system moves to another serving area, it registers at the registration directory of the current serving mobile data-intermediate system. (The registration service that is in the mobile serving function).

This mobile data-intermediate system then notifies the home mobile data-intermediate system of the current location of the mobile end system. Then the location directory of the home mobile data-intermediate system is updated by the registration service in the mobile home function. The home mobile data-intermediate system then sends a message to the old serving mobile data-intermediate system to delete the mobile end system record in its registration directory. The location registration procedure is illustrated in Fig. 2.

Network Protocol Data Unit (NPDU) forwarding. To route an NPDU to a mobile end system, the NPDU is first routed to the home mobile data-intermediate system according to the network entity identifier of the mobile end system (see Step 1 in Fig. 3). If the mobile end system is not in the home area, then the address of the current serving mobile data-intermediate system of the mobile end system is identified in the location directory. The NPDU is then encapsulated and tunneled to the current serving mobile data-intermediate system (see Step 2 in Fig. 3). This process is referred to as the redirection and forwarding service in the mobile home function at the home mobile data-intermediate system.

(Encapsulation is the process of enclosing the data within an NPDU inside another NPDU-header. This process is also known as "tunneling," since it can be used to hide the original NPDU-header information during delivery to the new NPDU destination specified in the encapsulated NPDU.)

Upon the receipt of the forwarded NPDU, the current serving mobile data-intermediate system decapsulates the NPDU and routes it to the cell where the mobile end system resides (see Step 3 in Fig. 3). This process is referred to as the readdress service in the mobile serving function at the serving mobile data-intermediate system.

The reader may query CDPD Forum Headquarters (info@forum.cdpd.net) to receive up-to-date CDPD information (such as existing CDPD systems, future applications expected and the money factor).

Read more about it

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About the author

Yi-Bing Lin received his BSEE degree from National Cheng Kung University in 1983, and his Ph.D. degree in Computer Science from the University of Washington in 1990. Between 1990 and 1995, he was with the Applied Research Area at Bell Communications Research (Bellcore), Morristown, NJ. In 1995, he was appointed full professor of Department of Computer Science and Information Engineering, National Chiao Tung University.

Glossary

CDPD–cellular digital packet data
CLNS–connectionless network services
DSMA–digital sense multiple access
MDBS–mobile data base station
MD-IS–mobile data-intermediate system
M-ES–mobile end system
MHF–mobile home function
MSF–mobile serving function
NEI–network entity identifier
NPDU–network protocol data unit
OSI–open systems interconnection
PDA–personal data assistant