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CDPD
Conceptual Overview

Product Note

Cellular Digital Packet Data (CDPD) is a system in which a robust packet data service can be added to existing Advanced Mobile Phone System (AMPS) cellular voice systems for a relatively small increase in base station cost. CDPD is a transparent overlay on an existing AMPS system. It makes use of AMPS channels that are not being utilized by voice traffic. Due to the multiple packet nature of CDPD, this system allows many users on a single channel, and can ultimately deliver additional revenue for minimal investment. Specifically, when utilizing sniffing and frequency hopping, CDPD does not require any additional antennas, filters, low-noise amplifiers, channel banks, or cell site buildings. More importantly, CDPD requires no additional frequency spectrum or licenses for these frequencies. Sharing installed infrastructure allows cellular carriers to grow their coverage quickly and inexpensively.

CDPD/AMPS Similarities:

- Full duplex radio channels
- Radio frequencies in the 800 to 900 MHz range
- 30 kHz channel bandwidth and separation
- Frequency reuse, coverage and power levels

Applications:

Service providers may leverage their existing cell site hardware to provide an entirely new type of service with minimal investment. The system utilizes unused AMPS air time and generates revenues that, prior to CDPD, never existed.

Revenue generation is based on the amount of information sent, not the time used. CDPD can be used for long data transmissions or short "bursty" type applications (the latter being more cost effective). This is important because customers do not want to be billed for an entire minute when actual data transmission only takes “x” seconds.

To illustrate this theory, a street vendor credit card payment example may be examined. Since land-lines are not readily available to street vendors, verifying credit cards real time requires a wireless modem. Using CDPD technology, a vendor can utilize a CDPD modem

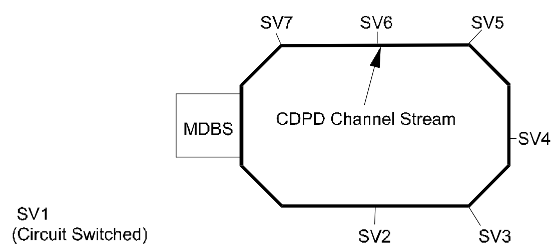
(Mobile End Station or M-ES), call at the beginning of the day and remain on the line for the entire day. This vendor is not charged for “y” hours of continuous service, but rather for the actual data sent (the short bursts of credit card information). On the other hand, without a CDPD modem, when a vendor needs to call for credit card verification at each point of sale, he or she will incur large overhead expsenses...see Figure 1. Instead of brief, few second transmissions using CDPD, it could take a minute or more for circuit switched modems (modems that use AMPS voice channels for data transmission) to perform activities such as establishing communications, handling protocol overhead, transmitting data, and so forth.

Additionally, CDPD has become very attractive to businesses that utilize device monitoring. For example, oil-head-monitoring and irrigation pumps have utilized CDPD modems to indicate current operating status from remote locations. Each pump can be accessed at any time without the cost of running a landline to each unit. Furthermore, these devices can be set up to broadcast emergency data messages when the unit experiences failures, providing immediate real-time information to the owners or operators.

Another application entails security systems. CDPD modems can tap a security system and monitor the status of the associated landline. If a burglar disconnects the landline, an emergency data message is broadcast via the CDPD modem. Essentially, CDPD service provides the perfect solution to this application, offering 24-hour monitoring of a land line with minimal billing since data is only sent in emergency situations.

All of these examples demonstrate CDPD's fundamental advantage: CDPD only costs the customer for the data sent and not the time required to send it.

Example: Illustrating the difference between CDPD and Circuit Switched Data transfer.
Below is a sketch of a typical channel stream for CDPD. In this example, street vendor 1 (SV1) uses a circuit switched modem (not part of CDPD channel stream) and SV2 - SV7 use CDPD modems for authorizing credit earned purchases real time.



Using a CDPD Modem, street vendor 2 (SV2) dials up at 8:00 AM and remains on line until 10:00 PM. While SV1 uses circuit switched service and calls when needed. **(Note**: SV2 is only charged for actual data sent and not the time on line.)

Comparison: Billing of 30 transactions per day consisting of 1 k-byte of data

SV1 Circuit switched
30 calls x Avg. 70 seconds per call (billing of 2 min.) x (.30 $/min) = $18.00

SV2 CDPD
30 x 1 k-bytes of information x $.10/k-bytes = $3.00

In this example, using circuit switched data transmission costs 6x the amount of CDPD. If this street vendor operated 300 days a year with an average of 30 transactions per day the operating cost using circuit switched would cost $5,400 a year vs. $900 with CDPD.

This example illustrates the economic and functional use of CDPD making it the data transfer technology of choice for this type of application.

Figure 1: CDPD vs. Circuit Switched Data Transmissions

Other CDPD examples include:

Internet	Company intranet
Electronic-mail	Public safety
Messaging	Query/response applications
Order Entry	Inventory search
Electronic trading	Smart phones (voice, e-mail, paging)
Package tracking	Utilities

How CDPD Works

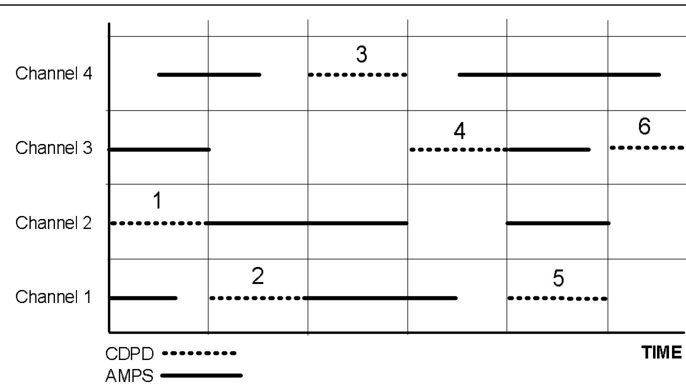
Sniffing & Channel Hopping

In practice, CDPD shares the voice system's radio frequency (RF) channels and avoids collisions with AMPS traffic via CDPD's unique methods of sniffing and channel hopping. The Mobile Data Base Station (MDBS) taps off (sniffs) a low-level RF signal from the transmit path of the voice network and analyzes it for voice activity. Since the MDBS must route its data traffic through unused voice channels, having an accurate account of AMPS channel traffic is imperative to CDPD's channel hopping success. An MDBS's sniffer utilizes a receiver that scans through each of the 30 kHz radio frequency channels sequentially and analyzes these radio frequencies looking for AMPS traffic every several milliseconds.

Most MDBSs utilize two forms of channel hopping, planned and unplanned.

Planned Hopping

A planned hop or timed hop, occurs after the MDBS has been transmitting for a pre-defined period of time, called channel dwell time.



Planned hopping:
A long CDPD data stream hops between channels for a specific defined period of time (equal channel dwell time).

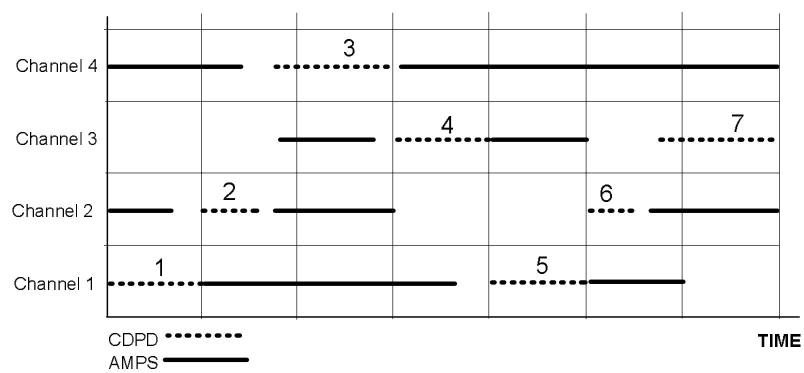
Figure 2: Planned Hopping

The time is determined by the network manager who bases this period in such a way that it will minimize interference with AMPS voice traffic. Since AMPS voice calls generally do not recognize CDPD traffic, AMPS might view CDPD as channel interference. Some voice systems see interference and end up shutting down that channel, making it unavailable for AMPS use. This phenomena is known as "channel sealing." Without timed hops, CDPD transmissions might eventually seal off all channels, completely shutting down the AMPS voice capability (the degree to which this occurs depends on cellular switch software design). To prevent sealing, a service provider must set the maximum dwell time to a value less than the period the switch software would take to register the CDPD signal as interference.

Another reason to employ planned hops is to increase efficiency. If all devices on the channel change channels simultaneously, and the channel destination is known by all, no additional delay in acquiring new compatible channels will be necessary. This yields more efficient hops.

Forced Hopping

The other type of hopping CDPD utilizes is called the forced hop. Forced hops occur when the sniffer detects AMPS energy and the MDBS shuts down the CDPD forward channel and tunes to another idle channel to resume data transmission. The CDPD 1.1 specification requires the MDBS to vacate that channel in 40 ms or less to be sure AMPS traffic is unaffected. Thus, a properly working, optimized sniffer receiver is critical to the success of a CDPD overlay system, otherwise AMPS traffic and its corresponding revenue may be adversely affected.



Forced hopping:
The sniffer detects AMPS energy causing the MDBS to shut the forward channel down and hop in concert with the M-ES to a new channel to resume data transmission.

Figure 3: Forced Hopping

Dedicated Channel Configuration

Alternatively, CDPD may be deployed in a "Dedicated Channel" configuration - offering an alternative to hopping frequencies. CDPD channels are assigned specific channels by the provider for sole CDPD usage. In these cases, special CDPD sniffer hardware/software is not necessary since the MDBS is not monitoring another network. However, this would require additional AMPS hardware or sacrifice existing AMPS channels. The current paradox facing service providers is that CDPD is being most utilized in the large Metropolitan Statistical Areas (MSA) where AMPS traffic is also peaking. When CDPD signals are constantly channel hopping to find open channels, data cannot be transferred and end users experience data latency. The major benefit dedicated channels provide is efficient throughput since channel hopping is not required. Therefore, in some areas, service providers have elected to utilize dedicated channels so CDPD can work efficiently and not interfere with AMPS traffic. Unfortunately, not using the sniffer and hopping option defeats the purpose of a CDPD overlay.

Physical Layer

The primary functions of the airlink interface physical layer are to provide a means for transmitting a sequence of bits as a modulated waveform, to receive a modulated data signal, and to demodulate it and reconstruct the sequence of received bits. The physical layer transmits and receives bits at the raw data rate of 19.2 kbps. Additionally, CDPD provides network layers offering robust encryption transmissions so transmissions cannot be monitored by radio scanners.

CDPD uses a Reed-Solomon (63,47) code which means data is transmitted as 63 symbols, each 6 bits in length (a total of 378 bits - see Figure 4). The 63 symbols are broken down into forty seven 6-bit symbols which carry user data (note user data is interleaved with busy/idle, decode status, and other bits) and sixteen 6-bit symbols which contain error correction and detection information. Since this digital signal must traverse an over-the-air RF interface for transmission, it must be robust enough to avoid channel interference that may corrupt data. A primary focus of CDPD protocol is to provide error correction for corrupted signals. A forward error correction protocol determined by CDPD pre-encodes a message with error correction bits so that even if a few bits are corrupted during transmission, the receiver is able to reconstruct the original data by executing a decoding algorithm without the need for re-transmission.

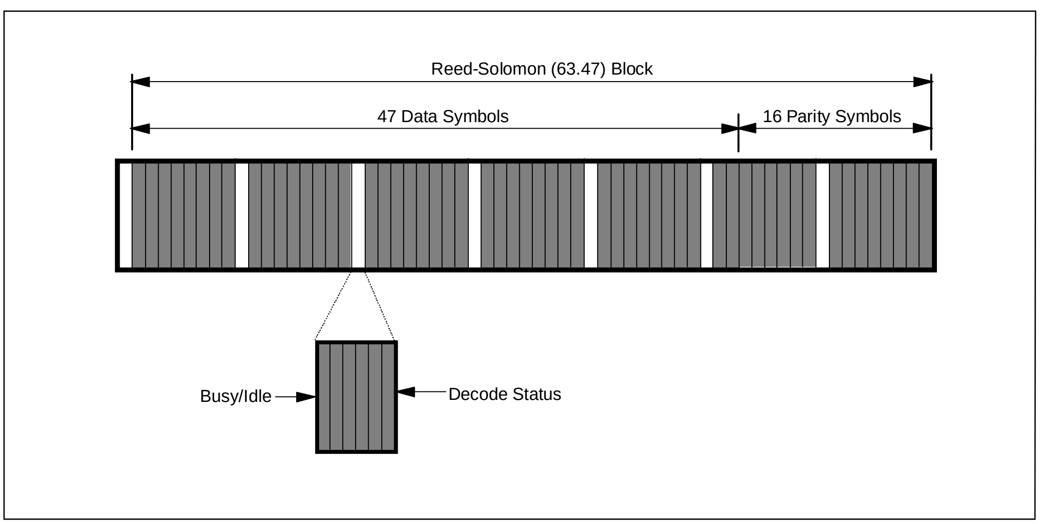


Figure 4: Forward Channel Block Structure

Depending on the implementation, CDPD error correction can reasonably correct up to eight 6-bit symbol errors.

The physical layer has the ability to measure the signal level of the received bits and control the power level used for transmission between the MDBS and the M-ES. More specifically, the MDBS controls the power transmitted by the M-ES with the use of two parameters broadcast in the forward Channel Stream Identification (CSI). The power product and maximum power level combine to control the transmit power of the M-ES. The maximum power level value restricts the transmit power of the M-ES and a constant power product has the effect of increasing the transmit power of the M-ES as it moves farther away from the MDBS.

CDPD uses Gaussian Minimum Shift Keying (GMSK) modulation with a 0.5 modulation index. In addition to relative ease of implementation, this particular modulation scheme and value correspond to a compromise for bandwidth efficiency and minimum signal power required to achieve a certain data rate at a given average bit error rate.

Medium Access Control (MAC)

The Medium Access Control (MAC) protocol layer conveys information between the logical link layers of the MDBS and M-ES across the physical airlink interface. Frame recognition, frame delimitation (beginning or end of data), and error correction and detection are included on both the forward and reverse channels.

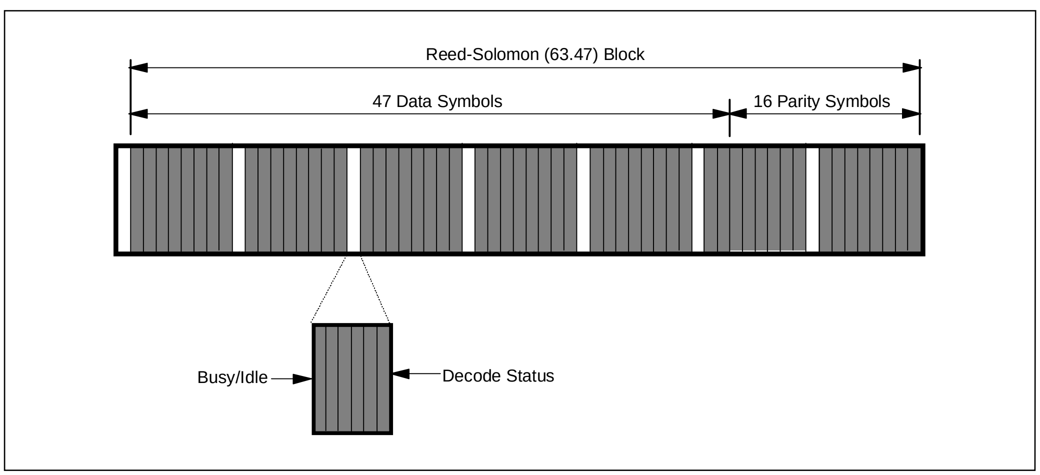


Figure 5: Channel Block Structure

The forward channel is an uninterrupted broadcast channel carrying a continuous stream of information from the MDBS to the M-ESs, except during channel hops. As previously mentioned, it consists of Reed-Solomon encoded mobile data link protocol packets that are 378 bits in length intermixed with control flags consisting of a portion of a synchronization word, decode status, and busy idle information (see Figure 5.) Throughput on the forward channel is 45.7 Reed-Solomon frames per second. Since each Reed-Solomon block is encoded using a (63,47) code word and contains extensive protocol overhead, CDPD's net data transfer rate yields approximately 9.6 kbps.

Furthermore, the MDBS uses the busy/idle flag to indicate if it is ready to receive information on the reverse channel or to indicate that it is busy with another M-ES. In other words, the MDBS toggles the busy/idle bit to the idle state when it is not receiving any packets and sets itself to busy when receiving an M-ES transmission. M-ESs which try to send information and cannot due to a busy MDBS flag must delay transmission for a random period of time and then re-check the MDBS's busy/idle flag.

The reverse channel is a shared channel (consisting of noncontinuous transmission streams) that may be accessed by all the M-ESs on a particular channel stream. An M-ES monitors the busy/idle flag of the forward control channel to decide if it can begin transmission.

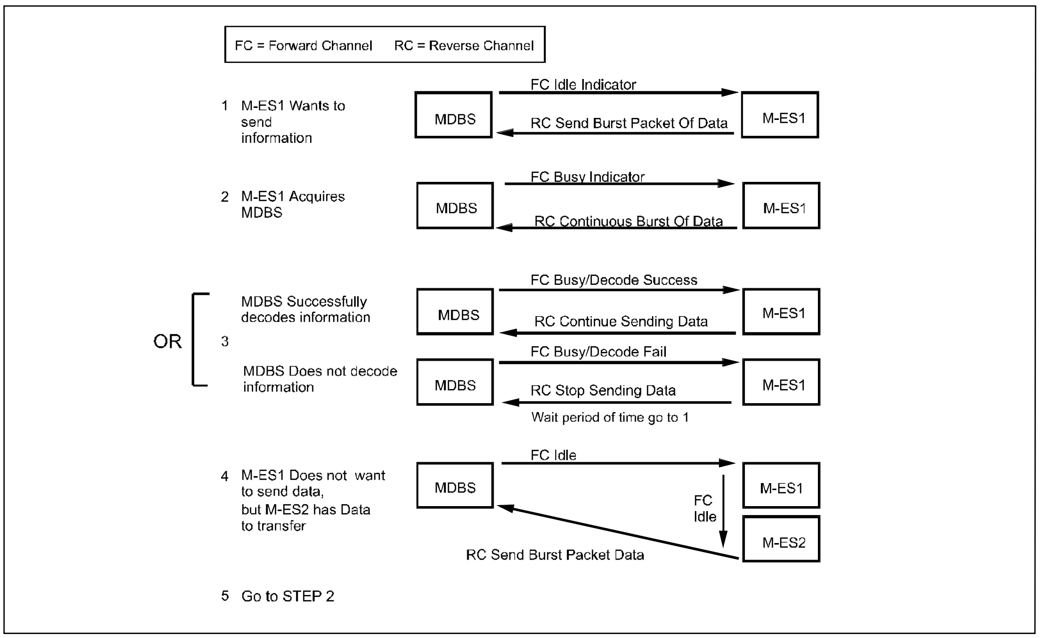


Figure 6: Process M-ES Acquisition of MDBS

These transmissions are composed of data bursts (one or more packets of 378 bits) and are preceded by a symbol timing recovery sequence, frame synchronization word, and inter-mixed control flags.

To further understand how CDPD works, it can be compared to a more familiar Ethernet network. For example, an Ethernet node first listens to a channel to see if another node is transmitting, if transmission is not occurring, it begins transmission. Similarly in CDPD, an M-ES checks the busy/idle flag on a channel stream and begins transmission if the flag is idle. If the Ethernet node detects transmission, it waits a random amount of time and tries again at a later time. In CDPD, if the M-ES detects a busy flag, it waits a period of time and then retries transmission. If the Ethernet network node senses any collisions or corrupted data, the network stops transmission, waits a random time, and then retries. Likewise, collisions may result if two or more M-ESs try to acquire an MDBS at the same time, thereby generating blocks with errors. In this case, neither M-ES's transmission will be successful and each M-ES will stop transmitting and retransmit at a later time.

When a M-ES tries to re-acquire the MDBS after a set period of time, successful transmission of the initial bit stream will turn the busy/idle flag to busy. At this point, the MDBS has acquired that particular M-ES and data throughput decode status is monitored. If the block error rate exceeds a certain threshold (implementation dependent), decode status indicates a failure and the MDBS tells the M-ES that it must send that block of

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information again. If block error rate is less than this threshold, decode status is read successfully and data transmission may continue.

Thus, two steps must occur for successful CDPD data transmission: 1. The M-ES must acquire the MDBS channel stream and 2. The MDBS must successfully decode the M-ES's bit streams. As more M-ESs contend for the reverse channel access (causing more collisions), a combination of error correction, auto retry, message spooling, and other protocol actions will result in inefficient throughput. When a system becomes bogged down with large amounts of data throughput, the network manager may alter channel utilization by regulating exactly how many M-ESs it may sustain on a particular channel stream (channel capacity flag) or, a network manager may reduce the sensitivity (and the number of users) of a radio by increasing the Busy/Set threshold level of the MDBS receiver.

Radio Resource Management

Unlike an AMPS voice system, the M-ES controls hand-offs using mobile-controlled hand-off procedures. Each CDPD MDBS continually transmits protocol data units on a channel stream to all local M-ESs so the M-ESs may create a database of information to control hand-offs. Parameters like Received Signal Strength Indicator (RSSI), Symbol Error Rate and Block Error Rate, all may determine when and where an M-ES switches between different MDBSs. Thus, the M-ES chooses the CDPD channel with the best signal strength, tunes to that channel, and tells the MDBS that it has entered the cell. From this point, the Mobile Data Intermediate System (MD-IS) updates the mobility manager such that all future data for that M-ES is routed to that cell.

Final Thoughts

In summary, CDPD provides an entirely new market to cellular AMPS carriers for minimal investment. Applications continue to grow as the need for wireless data transfer expands with the mobile office, device monitoring, smart phones, package tracking, and so forth. CDPD is a cost effective data transfer technology that, when used with a sniffer, fully leverages the existing AMPS infrastructure and frequencies.

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