Packet Data over Cellular Networks: The CDPD Approach

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ABSTRACT Cellular digital packet data is a mobile packet data technology that operates on the spectrum assigned to a telephone cellular network, such as the Advanced Mobile Phone Service. This article undertakes a thorough survey of the CDPD radio interface and explores the main functional layers of this interface. Specifically, it extensively studies the physical layer, the data link layer, and the subnetwork-dependent convergence protocol, and explains their semantics and functional characteristics. Furthermore, it emphasizes several significant aspects such as the medium access procedure, the forward and reverse channel configurations, the data multiplexing scheme, and the channel hopping procedure.

Cellular digital packet data (CDPD) is a mobile data technology that permits subordinate packet data operation on the spectrum assigned to a telephone cellular network, such as the Advanced Mobile Phone Service (AMPS). It was first introduced by IBM as a packet-switching overlay to the existing analog cellular voice network and frequencies. Later, a CDPD System Specification [1] was formed by a consortium of cellular carriers including AirTouch, McCaw Cellular, Southwestern Bell Mobile Systems, NYNEX, Ameritech, GTE, Bell Atlantic Mobile, and Contel Cellular [2]. Now, CDPD technology is being deployed by a number of cellular companies in the United States, including Bell Atlantic, Ameritech, GTE, and McCaw Cellular, and related equipment is provided by a variety of manufacturers.

An industry association that handles the shaping of CDPD technology and supports the growth of the commercial marketplace is the Wireless Data Forum [3]. According to this forum, by the end of the third quarter of 1997, CDPD was available in 195 markets in the United States — 118 metropolitan statistical areas (MSAs), 41 rural statistical areas (RSAs), and 36 international markets — and was available to 53 percent of the U.S. population.

This article focuses on the wireless interface of CDPD and explores the main functional layers of this interface. Specifically, the next section provides a general outlook on CDPD, and explains its major network elements and their interaction and functionality. The following three sections concentrate on the wireless interface and outline the physical, medium access control, and logical link control layers, respectively. In this context, several significant aspects are studied such as the medium access protocol, the forward and reverse channel configurations, and the data link establishment procedures. The article then focuses on the subnetwork-dependent convergence protocol (SNDCP), and demonstrates its major characteristics and the services it provides. The channel hopping procedure is underlined, and finally, the last section summarizes our conclusions.

A CDPD Overview

The primary elements of a CDPD network are the end systems (ESs) and intermediate systems (ISs), as shown in Fig. 1. (In Internet terminology, the ESs are known as *hosts* and ISs as *routers*.) The ESs represent the actual physical and logical end nodes that exchange information, while the ISs represent the CDPD infrastructure elements that store, forward, and route the information.

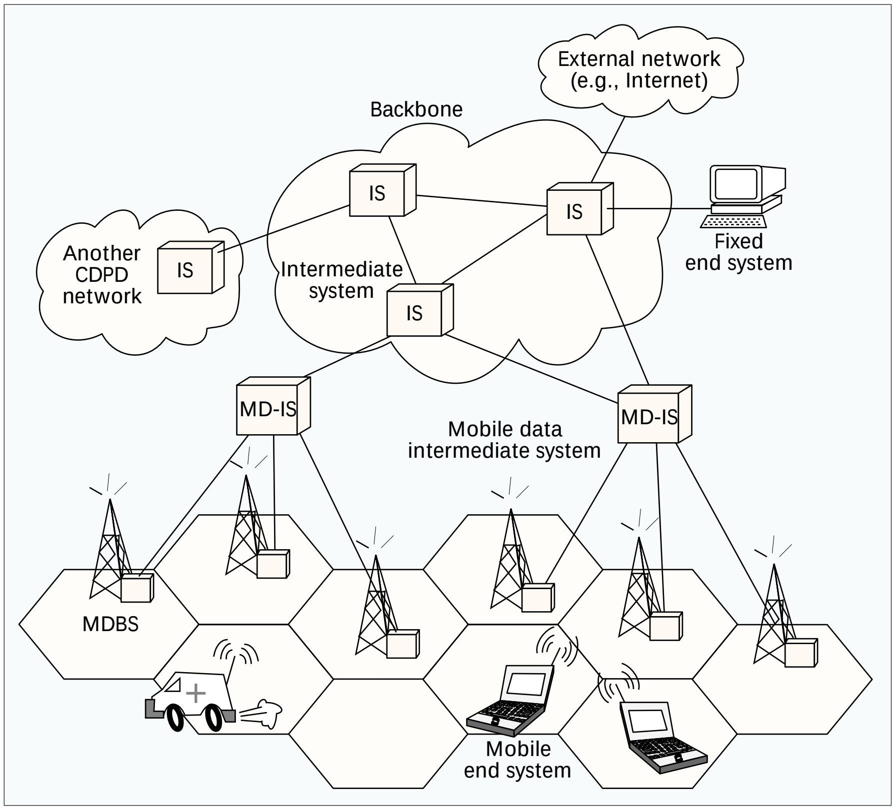
There are two kinds of ESs: The mobile ES (M-ES), which is a device used by a subscriber to access the CDPD network over the wireless interface, and the fixed ES (F-ES), which is a common host, server, or gateway connected to the CDPD backbone and providing access to specific applications and data. By definition, the location of an F-ES is fixed, whereas the location of an M-ES may change.

Typically, an M-ES consists of a *mobile terminal* (personal computer, personal digital assistant, or other standard equipment) and a CDPD *radio modem*, which attaches to the mobile terminal and manages the radio link and protocols. Usually, the communication between the radio modem and the mobile terminal is supported by standard serial protocols, such as the Serial Line Internet Protocol (SLIP) or Point-to-Point Protocol (PPP).

On the other hand, there are two kinds of ISs: a generic IS, which is simply a router (in most cases, an Internet Protocol, IP, router) with no knowledge of CDPD and mobility issues, and a mobile data IS (MD-IS), which is a specialized IS that routes messages based on its knowledge of the current location of M-ESs. The MD-IS is a set of hardware components and software functions that provide switching, accounting, registration, authentication, encryption, and mobility management functions. The mobility management software allows the switching system to track the M-ESs regardless of their location in the network and allows the M-ESs to use a single network address. The CDPD mobility management software follows the mobile IP model [4] established by the Internet Engineering Task Force (IETF).

Besides the ESs and ISs, there is also another element, the mobile data base station (MDBS), which is analogous to a common cellular base station. An MDBS performs no networking functions, but rather relays data link information between a number of M-ESs and their serving MD-IS (it is a data link functional element). Furthermore, it performs radio resource management procedures, the most important being the hopping of the CDPD radio frequency (RF) channel in response to voice network activity (see [5] for details). In summary, the MDBS creates and manages the air interface between the M-ESs and the CDPD backbone under the constraints arising out of the underlying voice network.

The CDPD backbone provides connectionless transport services, also called *datagram* services. This means that the network individually routes packets based on the destination address each packet carries and the knowledge of the current network topology. For the routing of packets, CDPD supports both IP and the Connectionless Network Protocol (CLNP), which is an open systems interconnection (OSI) standard protocol.



■ **Figure 1.** *General CDPD network architecture.*

The Physical Layer

As indicated in Fig. 2, the physical (PHY) layer in CDPD corresponds to a functional entity that accepts a sequence of bits from the medium access control (MAC) layer and transforms them into a modulated waveform for transmission onto a physical 30 kHz RF channel.

Communications between an MDBS and an M-ES take place over a pair of such RF channels (having a fixed frequency separation). The first channel, called the *forward* channel, accommodates transmissions in the direction from the MDBS to the M-ESs and is either dedicated to CDPD use or shared with the voice cellular network. In any case, transmission on the forward channel is continuous as long as it is in use for CDPD. The second channel, called the *reverse* channel, accommodates transmissions in the direction from the M-ESs to the MDBS and is shared among all M-ESs communicating with the same MDBS. A pair of associated reverse and forward channels forms a CDPD *channel stream*.

As illustrated in Fig. 2, the PHY layer interfaces with another entity, the radio resource management entity (RRME). Through this interface the RRME can:
- Tune the PHY layer to a specific RF channel pair
- Set the transmission power level to the desired value
- Measure the received signal level of an RF channel and estimate its potential to offer acceptable communication
- Suspend and resume operation of the PHY layer in cases where power saving facilities are required

The modulation employed on a RF channel stream is Gaussian minimum shift keying (GMSK) [6] with BT = 0.5. A frequency greater than the central carrier frequency represents a logical 1, whilst a logical 0 is represented by a frequency less than the central carrier frequency. The modulation rate on both the forward and reverse RF channels is 19.2 kb/s.

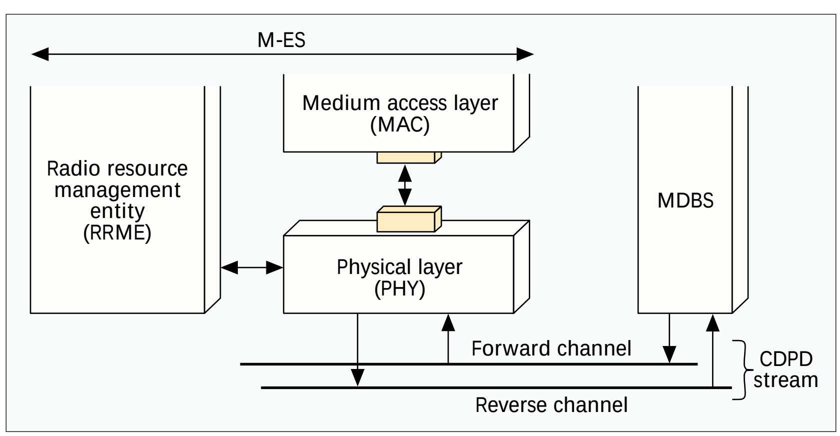
Medium Access Control

As shown in Fig. 3, the MAC layer models a functional entity logically operating between the PHY and link layer control (LLC) layers. The MAC layer within an M-ES cooperates with the corresponding MAC layer within the MDBS. The purpose of this layer is to convey information, namely link protocol data units (LPDUs), between peer LLC entities across the CPDP air interface. For this purpose, the MAC layer provides the following services:
- Encapsulates LPDUs into frame structures to ensure LPDU delimiting, frame synchronization, and data transparency
- Encodes LPDUs to provide error protection against mobile channel impairments
- Detects and corrects bit errors within received frames
- Arbitrates access to the shared reverse channel
- Synchronizes with the forward channel transmissions to make feasible the reception of data as well as control information transmitted in every CDPD cell

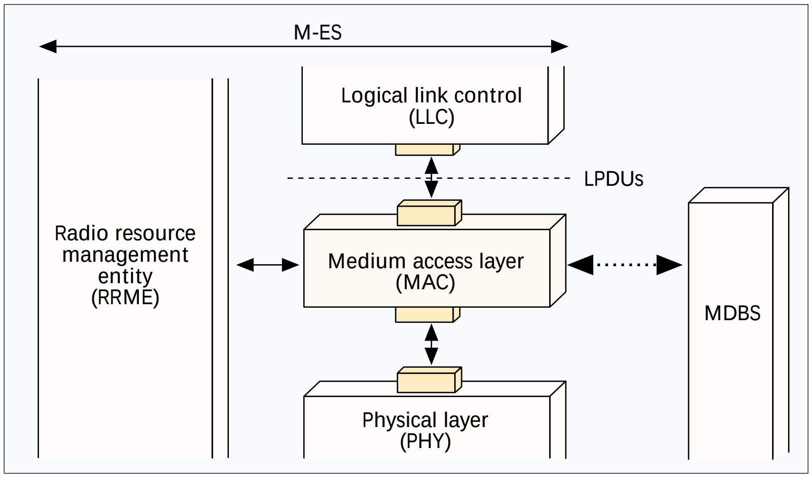
The MAC layer communicates through an implementation-dependent interface with the RRME. Through that interface, the MAC layer notifies the RRME whether it has acquired synchronization with the currently selected forward channel (next section), and also passes to the RRME status information regarding the number of received bit and block errors. In this way, the RRME may estimate the acceptability of a given CDPD channel and provide the radio resource management functionality [5].

Forward Channel Configuration

The forward channel characteristics are among the most essential issues required to understand CDPD operation. In order to



■ **Figure 2.** *The PHY layer model: operation and interaction with other functional entities.*



■ **Figure 3.** *An operational model of the medium access control layer.*

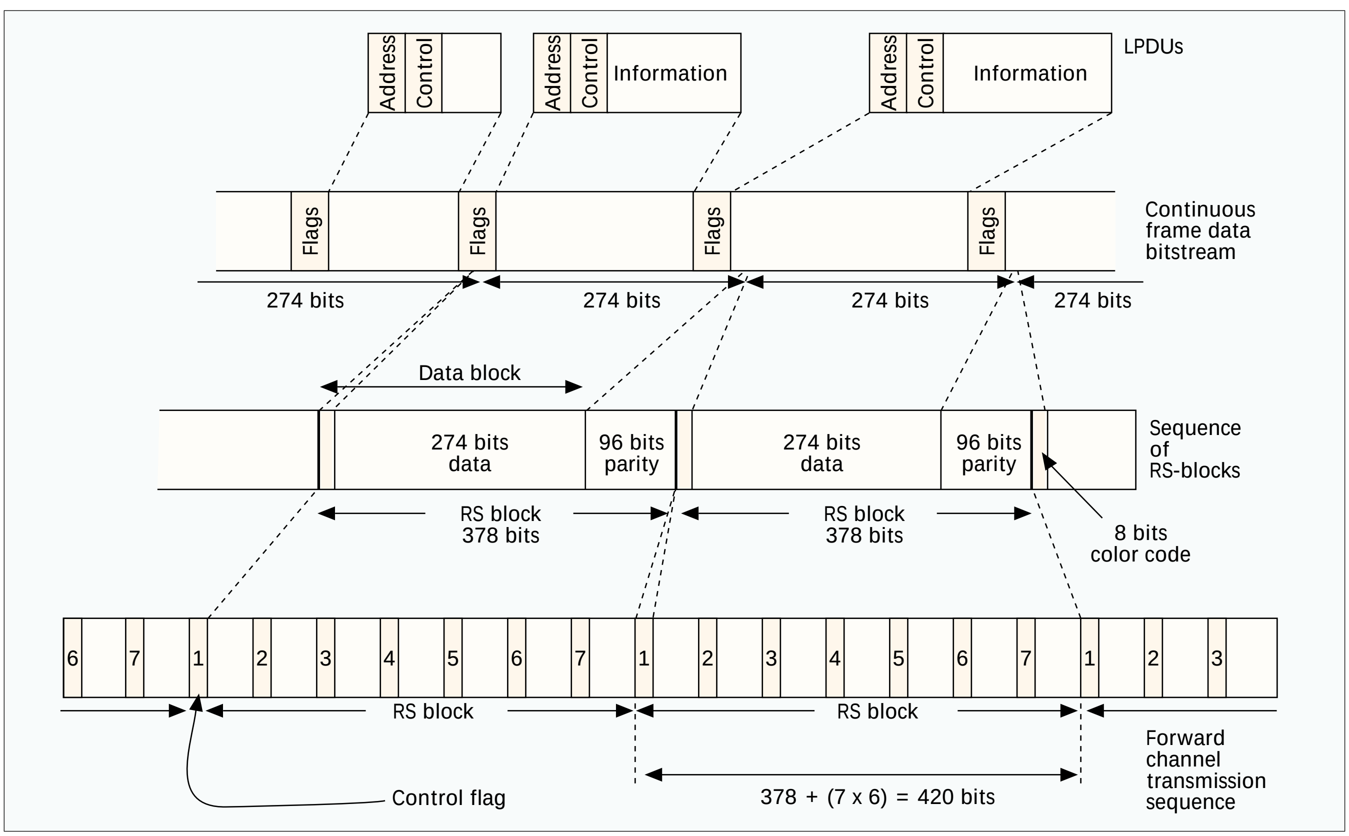
outline the configuration and the semantics of the forward channel, we will discuss how the LPDUs in an MDBS are transformed within a sequence of stages before they construct a continuous bitstream for transmission.

As shown in Fig. 4, the sequence of LPDUs pending for transmission are first flag-delimited (using the well-known bit pattern 01111110) and zero-stuffed, and then linked together to form a continuous frame data bitstream. The continuity of this bitstream is ensured because, even when there are no data LPDUs for transmission, either control LPDUs or sequences of contiguous flags are transmitted.

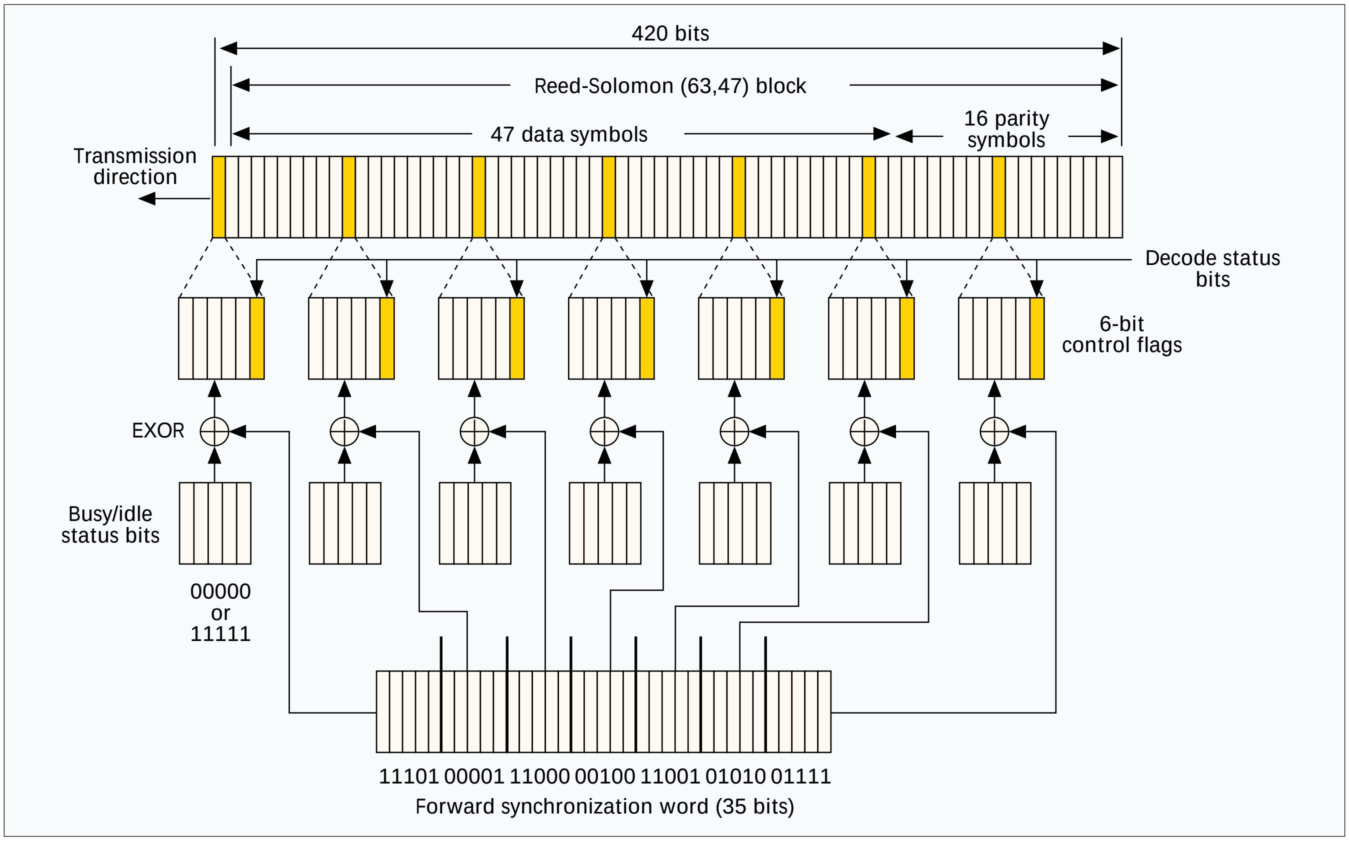
The frame data bitstream is divided into segments of 274 consecutive bits, each of which is prefixed by an 8-bit color code. Hence, a series of consecutive *data blocks* is formed, each with a fixed length of 282 bits. The color code is a special pattern assigned to every individual CDPD channel stream and is used for cochannel interference detection. Three bits within this pattern are MD-IS-specific; they have the same value in all channel streams transmitted in the set of cells controlled by a given MD-IS. On the other hand, the other five bits of the color code are MDBS-specific; they specify an individual channel stream within the set of cells controlled by a given MD-IS. Inside a cell, all RF channels available for CDPD use are assigned the same value of color code.

Data blocks are encoded using a systematic (63, 47) Reed-Solomon error correcting code. From an encoding point of view, each data block represents an information field of 47 6-bit symbols (or codewords). The encoding of this information field generates a 16-symbol parity field (96 bits), which is appended at the end of the information field. In this manner, a consecutive sequence of Reed-Solomon (RS) encoded blocks is generated, as shown in Fig. 4. These encoded blocks, each with a fixed length of 378 bits, form the basic transmission units of the forward channel. The (63, 47) Reed-Solomon encoding is common to both the forward and reverse channels and typically is capable of correcting as many as 8 bits within each encoded block.

Prior to actual transmission on the forward channel, each RS block is passed through a ninth-order scrambler with a generator polynomial, $g(x) = x^9 + x^8 + x^5 + x^4 + 1$. This process reduces the likelihood of having long strings of binary 1s and 0s within the transmission bitstream. Such long strings are generally avoided because they are difficult to track by certain



■ **Figure 4.** *Formulation of the forward channel data stream.*



■ **Figure 5.** *Detailed construction of a forward channel data stream.*

types of demodulators (e.g., PLLs) and may result in reduced performance or increased implementation complexity.

As illustrated in Fig. 4, what is actually transmitted on the forward channel is the contiguous sequence of RS blocks (after scrambling), interleaved with special control flags. These flags carry synchronization information that helps M-ESs acquire block synchronization and decode the forward channel, as well as MAC-level control information that helps M-ESs effectively share the common reverse channel.

Figure 5 illustrates in detail the forward channel transmission structure. It shows how the control flags are constructed and how they are interleaved with the forward channel RS blocks. Each control flag is composed of one *decode status* bit plus five more bits, which derive from an exclusive-OR operation between a 5-bit section of the *forward synchronization word* (FSW) and *busy/idle status* bits. The FSW is a 35-bit sequence that provides a reference marker within the forward channel bitstream to discriminate between control flags and RS block boundaries. Additionally, it provides a timing reference for the reverse channel *microslot clock*. This microslot clock as well as the decode status and busy/idle status bits form the primary elements of the MAC procedure and are discussed later.

Since the FSW is transmitted after being exclusively-ORed with the busy/idle status bits, its discrimination within the transmitted bitstream would be impossible if the value of busy/idle status bits was not known. Fortunately, as discussed later, the busy/idle status can be either 11111 or 00000; therefore, the 5-bit portion of the FSW carried within every control flag is either inverted (when the busy/idle status is 11111) or not inverted (when the busy/idle status is 00000).

An M-ES is actually synchronized with a forward CDPD channel as long as it can receive and decode the forward blocks of this channel with some acceptable error rate. If the level of error rate rises above a threshold, which is implementation-dependent (this is where commercial CDPD modems may defer), the M-ES starts searching through a series of RF channels to find another more suitable CDPD data stream (see [5] for details).

Reverse Channel Configuration

The structure of the data transmitted by M-ESs in a CDPD network (i.e., the structure of transmissions on the reverse channel) is now discussed.

Consider an M-ES having, for example, three LPDUs pending transmission, as illustrated in Fig. 6. These LPDUs are flag-delimited and zero-stuffed, and thereafter are joined together to form a frame data bitstream. The first 274 bits of this bitstream are prefixed by an 8-bit color code (which is the same as the color code transmitted on the forward channel) and form a 282-bit data block. The rest of the frame data bitstream is padded with interframe time fill (usually a consecutive sequence of 1s) and divided into an integer number of sequential data blocks, each 282 bits long.

All the data blocks formed this way are thereafter subject to (63, 47) Reed-Solomon coding, and thus a sequence of contiguous RS blocks, each with a fixed length of 378 bits, is constructed. After these RS blocks are scrambled, they are ready to be transmitted on the reverse channel. However, prior to their transmission are transmitted a) a 38-bit sequence of alternating 1s and 0s (the preamble), which helps the MDBS detect the transmission start and acquire timing synchronization; and b) a reverse synchronization word (RSW), which is a 22-bit pattern that helps the MDBS acquire block synchronization. The transmission of RS blocks follows right after the RSW.

As shown in Fig. 6, a 7-bit *continuity indicator* is interleaved with each RS block; 1 bit every nine 6-bit symbols. This continuity indicator is a sequence that signals whether the reverse transmission burst is completed or not. A sequence of all 1s indicates that more RS blocks follow, whereas a sequence of all 0s marks the final transmission block. Note that since the continuity indicator is not error-protected, it features high redundancy and time-diverse transmission (which effectively uncorrelates the errors that may occur within its 7 bits). Note also that the continuity indicator carries in-band information regarding the transmission progress, which results in more robust and less complex reception. Should the continuity indicator not be used, the moment a transmission ends would be derived from received signal analysis — a more complex and time-costly procedure.

THE MEDIUM ACCESS PROCEDURE

An M-ES can access the reverse channel using a slotted non-persistent digital sense multiple access with collision detection (DSMA/CD) algorithm. This is similar to carrier sense multiple access with collision detection (CSMA/CD) used in Ethernet. However, in CDPD because the M-ESs cannot sense the status of the reverse channel directly (because they employ different reception and transmission frequency bands), a different collision detection scheme is applied.

DSMA/CD makes use of the busy/idle and decode status flags. As previously stated, the busy/idle flag is a 5-bit sequence transmitted on the forward channel once every 60 bits (i.e., once every *microslot* period). This flag provides periodic binary information with one microslot resolution indicating whether the reverse channel is busy or idle.

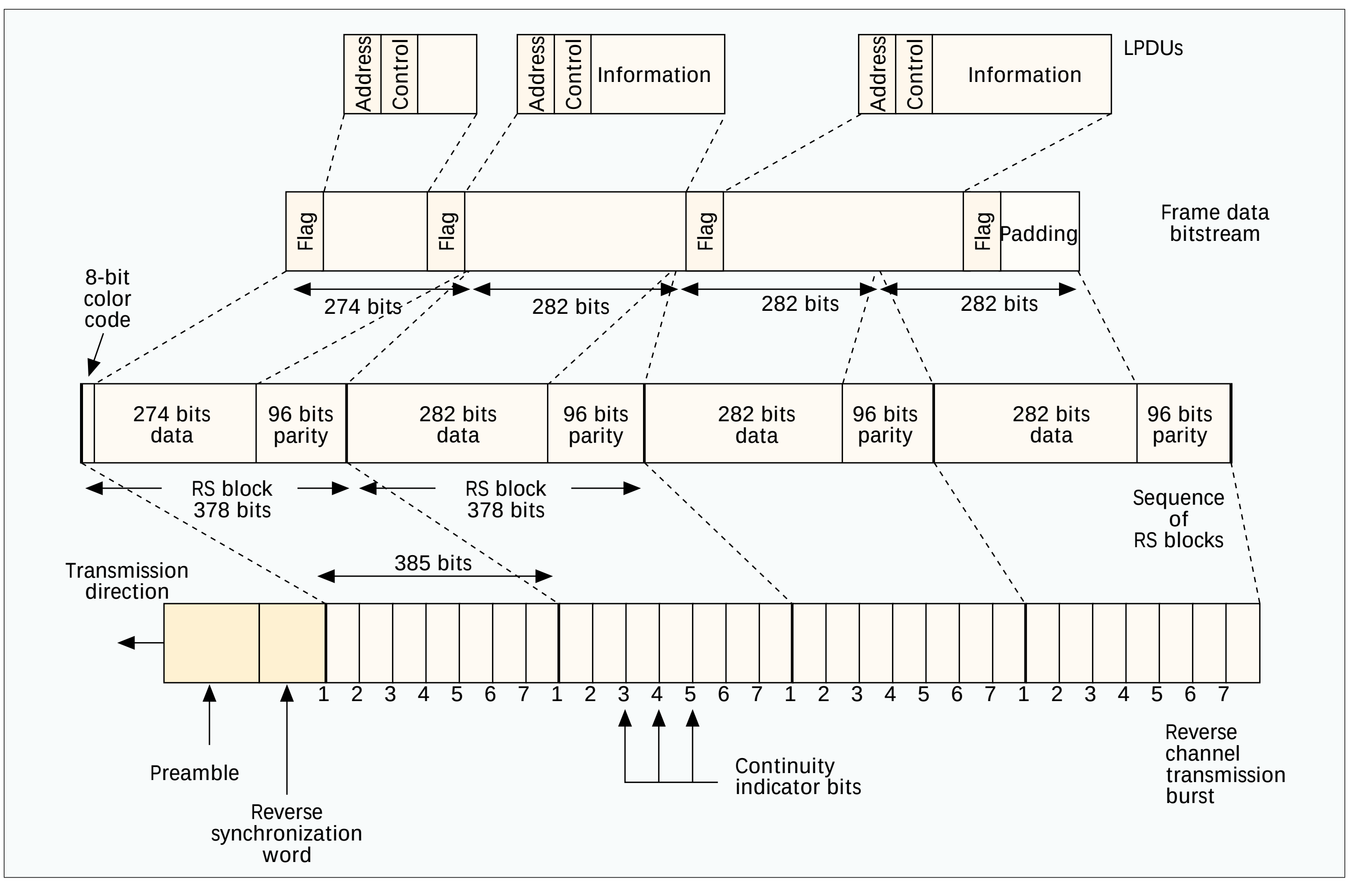
On the other hand, the decode status flag is a 5-bit[1] sequence that carries binary information indicating whether the MDBS has decoded the preceding block on the reverse channel successfully or not. On successful decoding the decode status flag is 00000, on unsuccessful decoding 11111.

An M-ES wishing to transmit senses first the busy/idle flag — actually, a locally stored version of it which is updated once every microslot period. If the reverse channel is found busy, the M-ES defers for a *random* number of microslots and then repeats the sensing of the busy/idle flag. Because the M-ES does not persist in continuously sensing the busy/idle flag, the access scheme is referred to as *nonpersistent*. Once the reverse channel is found idle, the M-ES may initiate transmission. Note that a transmission may initiate only at a microslot boundary, which is why the access scheme is termed *slotted*. As soon as the MDBS detects a transmission start on the reverse channel it sets the busy/idle flag in order to prevent further transmissions.

After an M-ES has started a transmission, it checks the decode status flag in every forward channel block it receives (this assumes full duplex operation[2]) and resumes or suspends transmission depending on the value of this flag. This flag provides "real-time" information regarding the progress of its ongoing transmission. The M-ES continues transmission if the decode status flag indicates that the MDBS encountered no decoding errors so far, whereas it ceases transmission in the opposite case (note that the MDBS cannot distinguish between errors due to collision and those due to channel impairments). In the latter situation, the M-ES attempts to regain access to the reverse channel after an appropriate

[1] *Although M-ESs decode a 5-bit decode status flag, the MDBS transmits 6 or 7 bits of decode status per reverse channel block; the exact number depends on the relative timing difference between the forward and reverse channels [1].*

[2] *M-ESs may be either full-duplex or half-duplex. Half-duplex M-ESs are subject to certain restrictions regarding access to the reverse channel due to their inability to receive the decode status flag while transmitting.*

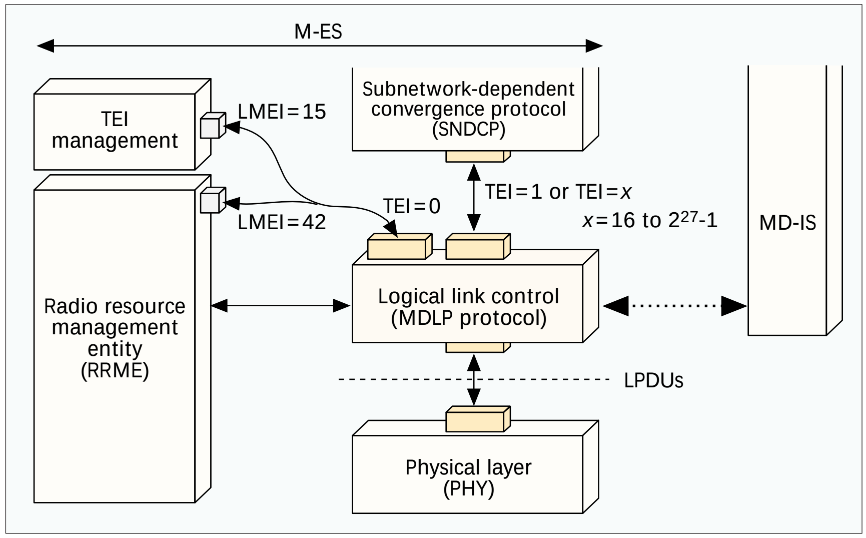


■ **Figure 6.** *Detailed construction of the reverse channel bitstream.*

exponential backoff retransmission delay. This delay is increased exponentially by a factor of two on every subsequent retransmission attempt; hence the name *exponential backoff*.

LOGICAL LINK CONTROL

The purpose of the LLC layer is to convey information between network-layer entities across the CDPD air interface. The protocol applied in the context of this layer is called Mobile Data Link Protocol (MDLP). As illustrated in Fig. 7, MDLP implemented in an M-ES communicates with a peer MDLP located in its serving MD-IS. Hence, it is seen that the functionality of an MDBS is restricted within the PHY and MAC layers. Above the MAC layer, an MDBS is completely transparent.



■ **Figure 7.** *The model of the LLC layer and its interaction with other entities.*

The primary service offered by the MDLP to the upper layer (the SNDCP) is the provision and control of one or more logical data link connections on a CDPD channel stream. Above the LLC layer, these data link connections are treated as individual bit pipes that may be used to convey messages back and forth between an MD-IS and one or more M-ESs. Within each data link connection, one or more network traffic flows may be accommodated through facilities provided from the SNDCP.

Discrimination between data link connections is by means of an address label contained in each message (also called *frame*). This address label is called a *temporary equipment identifier* (TEI) and is a pure LLC layer concept; it is used internally by the LLC layer and is not necessarily known by other functional layers.

A data link connection may be either *point-to-point* or *broadcast*, depending on its endpoints. A broadcast data link is used for point-to-multipoint or multipoint-to-point communications on a CDPD channel stream. Two broadcast data links are specified employing two predefined and well-known values of TEI:

- A channel with TEI = 1 identifies a layer 3 broadcast channel. According to Fig. 7, all received frames from this channel are forwarded to the SNDCP. This broadcast channel is used *only* by the network side (the MD-IS) to transmit certain control information.
- A channel with TEI = 0 identifies a broadcast channel used for *data link management* procedures. As shown in Fig. 7, frames from this channel are delivered either to the TEI management entity or to the RRME depending on the layer management entity identifier (LMEI) value. With the aid of this channel, the RRME within an M-ES receives radio resource management information that is broadcast in every CDPD cell (see [5] for details). Typically, it receives *channel stream identification* parameters, *cell configuration* parameters, *channel access* parameters, and *channel quality evaluation* parameters.

In contrast to broadcast data links, point-to-point data links are single-ended and used to convey information between a single M-ES and its serving MD-IS. Before a point-to-point data link connection is established, a specific TEI value (from the range 16 to $2^{27} - 1$) is allocated to the M-ES that is associated to this connection (see [1] for details). Thereafter, the M-ES transmits on the point-to-point connection using the allocated TEI value and accepts all received frames containing the allocated TEI value. Hence, the TEI is used as a channel identifier or an M-ES data link address. Typically, every M-ES is allocated a single TEI value, which is used to multiplex all network-layer traffic between this M-ES and its serving MD-IS.

Two operation modes are supported for information transfer within a data link connection: unacknowledged and acknowledged. Information transfer on a broadcast channel is carried out using only the unacknowledged mode, wherein neither error recovery nor flow control mechanisms are applied. Therefore, information transfer with the unacknowledged mode provides for unreliable transmission. On the other hand, information transfer on a point-to-point data link channel is carried out using either the *unacknowledged* or *acknowledged* mode of operation, depending on the quality of service required by the network layer. For every acknowledged mode data link connection, the MDLP establishes control mechanisms in order to ensure a given level of service quality. For example, the MDLP provides sequence control to maintain the sequential order of the frames across the data link connection. Also, it detects several errors, initiates procedures to recover from them, and provides flow control.

FRAME STRUCTURE

Information transfer between peer LLC entities is carried out through a number of frames or LPDUs. The general structure of a frame is illustrated in Fig. 8. The address field specifies whether the frame is a command or response (field C/R) and identifies the virtual data link channel that carries the frame via the TEI value (in other words, for a point-to-point link it identifies the intended receiver of a command frame and the transmitter of a response frame). The extension address (EA) field is used to indicate the length of the address field.

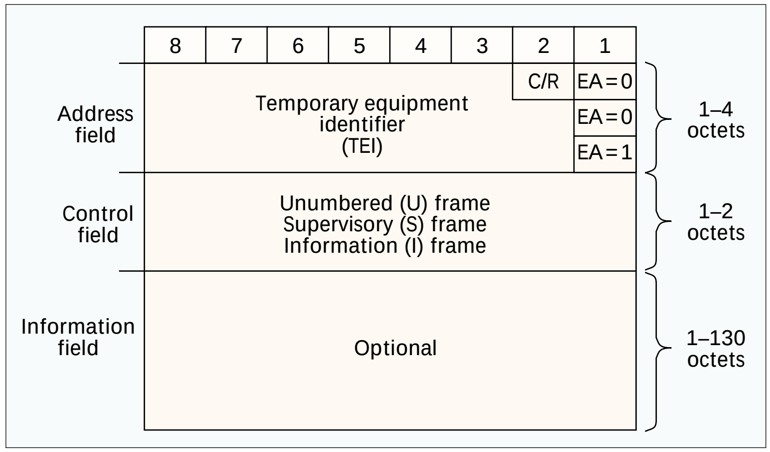
The control field identifies the generic type of the frame, which can be one of the following: numbered information (I), supervisory (S), and unnumbered (U). S frames are used to perform data link supervisory control, for example, to acknowledge the reception of correct I frames or request the retransmission of erroneous frames. U frames are used to provide additional control functions (e.g., the establishment and release of data link connections) and to transfer data using the unacknowledged information transfer mode.

Observe that no frame check sequence (FCS) field is included in a frame because the MDLP does not need to detect any errors. This is done at the MAC layer, which discards the frames containing unrecoverable numbers of errors and forwards only correct frames to the MDLP. However, the MDLP identifies the missing frames (which have been dropped at the MAC level) by checking the sequence numbers, whereupon it requests their retransmission.

INFORMATION TRANSFER

During the lifetime of a data link, information transfer is based on a sliding window (with a window size of 128 frames) protocol with a selective repeat scheme for error recovery. This is a well-known method for information transmission and will not be discussed further in this article. The MDLP uses special frames, selective reject (SREJ) frames, to report missing data frames and request their retransmission in order to keep the data integrity.

Generally, the concepts and procedures applied to MDLP are based extensively on International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) Recommendations Q.920 and Q.921, which specify the Link Access Procedure for the D-channel (LAPD) protocol. Many of the formats and procedures between the MDLP and LAPD are similar or nearly identical with some minor differences, for example, in addressing formats and TEI management procedures. For more details, the reader is referred to [1].



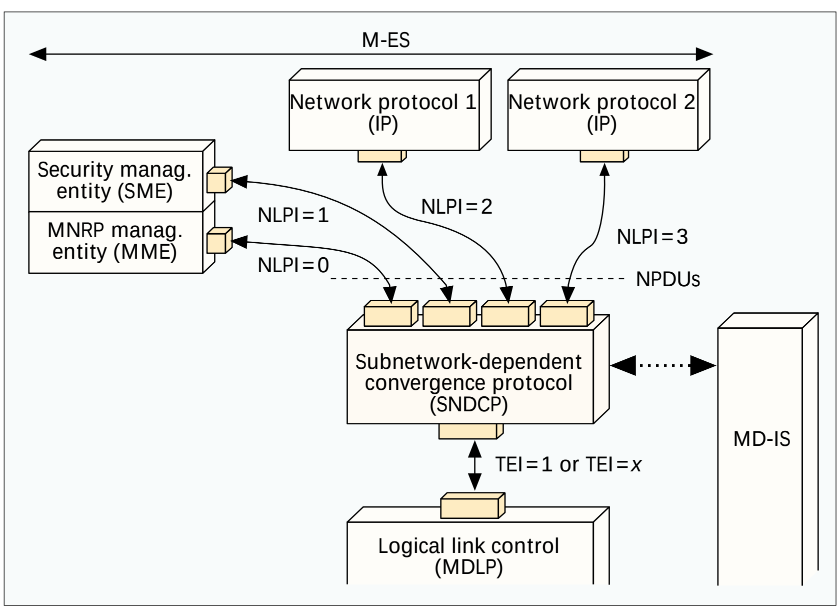
■ **Figure 8.** *The structure of MDLP frames.*

SUBNETWORK-DEPENDENT CONVERGENCE PROTOCOL

Functionally, SNDCP lays between the data link and network layers. The latter is assumed to be subnetwork-independent; it is built to work virtually over any data link, and therefore does not take into account the specific features of the MDLP. For this reason, the services assumed by the network protocol(s) may not map directly into the services provided by MDLP. In this case, SNDCP operates to provide the required cooperation.

More specifically, SNDCP provides the following functions:

- *Segmentation:* Network protocol data units (NPDUs) are segmented and reassembled where needed in order to be accommodated within the limited length of the data link frames. With this segmentation, the maximum size of an NPDU can be 2048 bytes, while the maximum size of user data supported by MDLP is considerably smaller (default value 130 bytes).
- *Encryption:* To provide user data confidentiality over the CDPD air interface, NPDUs are encrypted after being segmented. The secret keys used for encryption and decryption are obtained by means of a security management entity (SME) that operates on top of SNDCP as a network layer entity (Fig. 9).
- *Multiplexing:* SNDCP provides the means to multiplex several network-layer traffic types within the same data link connection (note that this facility is not provided by the MDLP). This makes feasible the simultaneous utilization of various network-layer entities on top of SNDCP. For example, as indicated in Fig. 9, two network protocols (IP and CNLS) as well as two management entities (the SME and the Mobile Network Registration Protocol,[3] MNRP, management entity) may simultaneously operate on top of SNDCP. Each is distinguished by its own network-layer protocol identifier (NLPI).
- *Header compression:* SNDCP compresses and recovers redundant network control information to increase data link performance and efficiency.
- *Data compression:* To further increase data link performance, the data portion of the NPDUs is compressed according to ITU-T V.42 bis (as in all V.34-compliant wireline modems).
- *Quality of service:* Two data transport modes are provided by the SNDCP: the acknowledged mode, which transfers NPDUs within the data link control procedures, and the unacknowledged mode, which transfers NPDUs outside the data link control. The transport service mode utilized depends on the *quality of service* parameter requested by the network layer.



■ **Figure 9.** *The model of SNDCP and its interaction with the other entities.*

CHANNEL HOPPING

Since CDPD was specified after the telephone cellular networks were already in operation, its design was subject to the constraint that no changes should need to be made to the existing cellular systems. For this reason, CDPD has been designed to be

[3] *After establishing a point-to-point data link connection and exchanging the ciphering keys, an M-ES uses the MNRP to authenticate and register all the network protocols it employs. Besides providing an additional level of security, the MNRP lets the MD-IS obtain information about the network addresses of an M-ES and route its packets accordingly.*

completely transparent to the underlying cellular systems. Consequently, when a cellular system selects a new channel for voice transmission, it is not aware of the existence of CDPD, and therefore it may acquire the channel currently used by CDPD. In that case, the CDPD channel stream should be preempted as soon as possible (voice has priority over data) and established on another idle channel to continue CDPD operation. In effect, CDPD operates in a channel hopping environment, which has several effects on its downlink performance [7].

The means by which the MDBS finds an available channel for transmission is implementation-specific. Typically, either a suitable communication protocol is implemented between the MDBS and the cellular base station, or monitoring devices (known as *sniffers*) are employed [1]. In the latter case, the MDBS monitors the transmit signal of the cellular base station by sensing the power that enters its transmit antenna. As soon as a power ramp up is detected, which indicates the initiation of voice traffic, a *forced* channel hopping procedure begins. (A channel hop may also be *planned* because there is a maximum amount of time — 1 min by default — that an MDBS is permitted to dwell on a particular RF channel).

In any type of channel hop, the MDBS closes down the current forward channel by ceasing transmission (before any voice is transmitted), hops on a new idle cellular channel, and starts transmitting its forward data traffic on that channel. M-ESs will need to track the channel hopping and may have to hunt around among a designated set of potential CDPD channels before they find it.

Conclusion

CDPD is a relatively new mobile data technology that has begun to spread in North America. Its unique characteristic is the ability to be implemented as either an independent cellular system or a packet-switching overlay to the existing cellular telephone network. In the latter case, CDPD may experience fast deployment and minimum installation cost by taking advantage of the available cellular infrastructure. However, the choice of whether it will be implemented on dedicated RF channels or not depends on the imposed service requirements. Obviously, a nondedicated approach is subject to strong affection by the traffic activity of the underlying cellular system, and therefore to reduced performance. It is anticipated that as CDPD grows in popularity, providers will be more likely to reserve channels exclusively for it.

In any case, CDPD is an interesting technology, and this article provides a thorough study of its wireless interface, which features enhanced characteristics and efficient functionality. By means of channel hopping, CDPD can suck up any idle capacity in a cell without interfering with the underlying cellular system.

References

[1] CDPD Forum, CDPD Specification 1.1, Jan. 1995.

[2] AirTouch Cellular, Technical Paper Series, *Introduction to the CDPD Network*, 1995.

[3] Wireless Data Forum (formerly CDPD Forum) Web site: http://www.wirelessdata.org

[4] C. E. Perkins and P. Bhagwat, "A Mobile Networking System Based on Internet Protocol," *IEEE Pers. Commun*., 1st qtr. 1994, pp. 32–41.

[5] A. K. Salkintzis, "Radio Resource Management in CDPD Networks," submitted to *IEEE Pers. Commun*.

[6] K. Murota and K. Hirade, "GMSK Modulation for Digital Mobile Radio Telephony," *IEEE Trans. Commun*., vol. COM-29, July 1981, pp. 1044–50.

[7] A. K. Salkintzis, "Effective Forward-Channel Capacity of Non-Dedicated CDPD Networks," submitted to *IEEE Commun. Lett*.

Biography

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