Designation: PS 105 – 99

Standard Provisional Specification for Dedicated Short-Range Communication (DSRC) Data Link Layer[1]

This standard is issued under the fixed designation PS 105; the number immediately following the designation indicates the year of original adoption.

INTRODUCTION

This provisional specification was prepared by ASTM Committee E17 on Vehicle-Pavement Systems, Subcommittee E17.51 on Dedicated Short Range Communications (DSRC), using its Layer 2 Task Group to pursue its objective.

This provisional specification is intended to form a part of a series of standards defining the framework of the Dedicated Short Range Communication (DSRC) link in the North American Intelligent Transportation Systems (ITS) environment. In addition to this provisional specification, the following parts will also be issued by ASTM E17.51 (and others) to form a complete set of standards for the DSRC link.

The standard documents and technical reports, relevant for DSRC are as follows: ASTM PS 111. A complimentary standard has been developed by CEN and adopted as a work item by ISO standards setting organizations covering Layer 2: prENV278/9/#64: DSRC Data Link Layer: Medium Access and Logical Link Control.;[2] A document that is a companion to the CEN standard has been developed by a consortium of European equipment manufacturers: Global Specification for Short Range Communication.

The Layer 2 Task Group consists of experts mainly from telecommunication sector and also from transport sector. The most active participating companies and organizations are: interest groups/associations; equipment manufacturers; systems integrators; toll/Turnpike Agencies; and research Consultants.

Additional inputs came from non-American experts from Europe and Japan.

It is important to note that this provisional standard is not designed to provide backwards compatibility with any existing equipment. However, in recognition of the substantial deployment of DSRC equipment in North America to support a number of applications, the Committee E17 resolves that: It reaffirms the results of the work undertaken by Subcommittee E17.51 and reaffirms its commitment to the draft DSRC standards (Layer 1, Layer 2, and Layer 7) for North American use.

It also recognises that already established and deployed systems in large scale should be tolerated as long as they are in the public domain and can co-exist with the North American DSRC standards developed by ASTM and IEEE. Furthermore, the committee wishes to enable and encourage their migration towards full interoperability.

It requires that the path by which interoperability and migration is to be achieved remains the responsibility of equipment vendors, system integrators and the user community. (An approach to achieve interoperability is provided in Appendix X1.)

INTRODUCTION

Dedicated Short-range Communication (DSRC) is intended to meet the requirements of many of the DSRC applications defined by the National ITS Architecture and the Intelligent Transportation Society of America. These applications include Advanced Traveller Information Systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control Systems (AVCS), Electronic Toll and Traffic Management Systems (ETTM), Advanced Public Transportation Systems (APTS), and Advanced Transportation Management Systems (ATMS).

This provisional specification comprises requirements for Open Systems Interconnection (OSI) Layer 2 DSRC Data Link Layer: Media Access and Logical Link Control. This provisional specification does not include associated measurement procedures for verification of the requirements. Measurement guidelines are intended to be developed in another document, as a separate work item.

This provisional specification applies to active and backscatter transmission technologies, and allows for interoperability between systems based on both of these technologies. Furthermore, this provisional specification allows for mixed time, frequency and space division multiple access approaches.

1. Scope

1.1 This provisional specification defines the Open Systems Interconnection (ISO7498 : 1984) Layer 2 data link layer for dedicated short-range communication (DSRC) equipment operating in half-duplex mode.

1.1.1 This provisional specification defines the Data Link Layer irrespective of the physical medium to be used. However, it is expected that the standard will be used in accordance with a three layer stack as defined by Subcommittee E17.51 and IEEE P1455 and illustrated in Fig. 1. A critical implication of the use of the Data Link Layer standard with PS 111 is the assumption that the data rate will be 500 Kbps on both the uplink and downlink.

1.1.2 This provisional specification specifies dedicated short range communications between fixed equipment at the roadside, called a beacon or Road Side Equipment (RSE) and Mobile Equipment in vehicles, called a Transponder or On-Board Equipment (OBE). This standard does not address vehicle-to-vehicle communication or communication between different instances of RSE.

1.1.3 This provisional specification adheres to the general DSRC architecture in which the RSE controls the medium, allocating its use to OBEs within range of the RSE.

[1] This provisional specification is under the jurisdiction of ASTM Committee E17 on Vehicle Pavement Systems and is the direct responsibility of Subcommittee E17.51 on Dedicated Short Range Communications (DSRC).

Current edition approved Dec. 28, 1999. Published April 2000.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

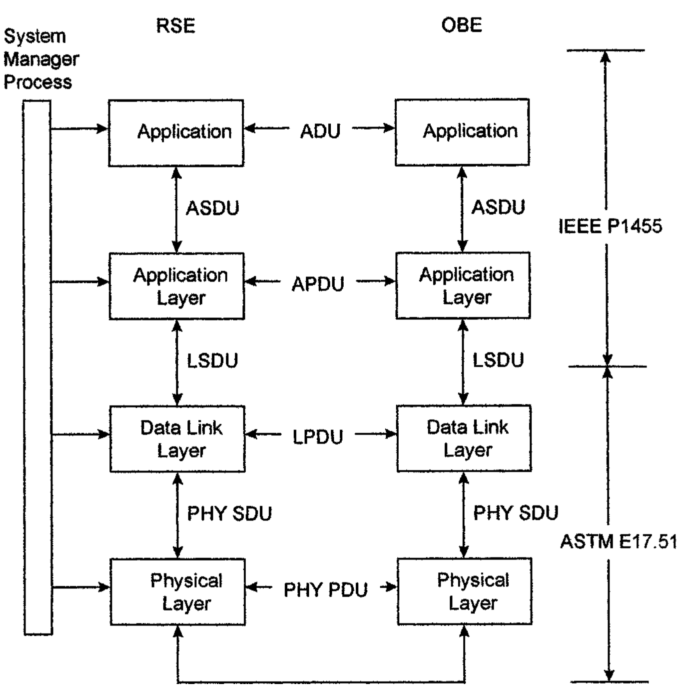

FIG. 1 Data Flow Between Communication Layers

1.1.4 This provisional specification supports a variety of RSE configurations. It supports configurations where one RSE communicates with one OBE, as well as configurations where one RSE can communicate with several OBEs. It does not define any specific configuration or layout of the communication zone.

1.1.5 This provisional specification does not define to what extent different instances of RSE, operating in the vicinity of each other, need to be synchronised with each other.

1.1.6 This provisional specification defines parameters to be used in negotiation procedures taking place between RSE and OBE.

1.1.7 This provisional specification defines the following:

1.1.7.1 Medium access control (MAC) procedures for the shared physical medium,

1.1.7.2 Addressing rules and conventions,

1.1.7.3 Data flow control procedures,

1.1.7.4 Acknowledgement procedures,

1.1.7.5 Error control procedures,

1.1.7.6 Services provided to data link user(s), and

1.1.7.7 Fragmentation.

1.1.8 There are two primary MAC modes, synchronous and asynchronous. Both modes support time-division multiple access half-duplex communications combined with a slotted aloha protocol for activation. The synchronous mode is characterized by a contiguous set of slots which is transmitted continuously and has fixed polling, data communications and activation phases. The asynchronous mode can vary the transmission of polling sequences, activation attempts or data communications.

1.1.9 This provisional specification assumes that each RSE covers a limited part of the road (the communication zone) and that the OBE communicates with the RSE while passing through the communication zone.

1.1.10 This provisional specification specifies the services required of the data link layer by the DSRC data link layer user, as viewed from the data link layer user, to allow a data link layer user entity to exchange packets with remote peer data link layer user entities. The services do not imply any particular implementation or any exposed interface.

1.1.11 Not discussed in this provisional specification are signals that must be passed through the Data Link Layer from the Physical Layer to the Application Layer or vice versa in the OBE. These signals include indications of exceeding the wake-up threshold level (to control the OBE response in a small zone) and no carrier (to permit graceful shut down of the OBE if the OBE unexpectedly loses communications). It will be necessary to consider the implementation of these signals in OBE design.

1.2 *Overview*:

1.2.1 All transmissions by either the RSE or OBE shall consist of a preamble and a frame. A preamble is an eight-bit sequence used for bit synchronization and is specified in Layer 1. A frame is a data link layer entity, which is the result of encapsulation of an application protocol data unit. The generic encapsulation process is shown in Fig. 2.

1.2.2 An APDU is delivered from the application layer to the data link layer. If the APDU cannot be sent in a single transmission, then it is subdivided into multiple packets. Each packet is then converted into an LPDU by appending a byte count, fragmentation and logical link control and status field to the beginning of each packet. The frame is then formed by appending a link address field, and media access control field to the beginning and a error detection check field to the end of each LPDU. Each frame is then sent to the physical layer, which appends the preamble and then transmits the data.

1.2.3 The frames can be transmitted in one of two modes: synchronous or asynchronous. In the synchronous mode, frames are transmitted in one of three types of slots: frame control message, message data or activation. The slots are combined to form a continuously repeated TDMA frame, as shown in Fig. 3. Each TDMA frame begins with a frame control message slot (FCMS). The FCMS only contains a frame control frame which is a broadcast message from the RSE indicating the number of slots, the type of each slot and the size of the slots that compose the rest of the TDMA frame. For example, in Fig. 3, the frame control frame defines a TDMA frame composed of three additional slots, two slots for data transmission and the other slot for activation. The message data slot (MDS) contains a data message frame transmitted over either the downlink to a specific OBE or uplink from a specific OBE. In addition, there is an acknowledgement transmitted immediately after the data message frame in the opposite direction. The activation slot (ACTS) consists of activation windows which are time periods when any OBE is allowed to transmit in contention with other OBEs in order to attempt to activate. It is not necessary to have an activation slot in a TDMA frame.

1.2.4 Assuming link establishment requires the transmission of a beacon service table (BST) from the RSE and negotiation of link parameters using a vehicle service table (VST), Fig. 4 provides an example of a full link negotiation followed by a read/write operation in synchronous mode. (Note that the full link negotiation can be shortened to reduce the number of TDMA frames needed to complete a transaction.) In TDMA Frame #1, the OBE receives a BST from the RSE and decides to activate. The activation is also transmitted in TDMA Frame #1. In TDMA Frame #2, the frame control frame designates a downlink message data slot to obtain the VST. After the OBE transmits the VST in TDMA Frame #2, the RSE commands the

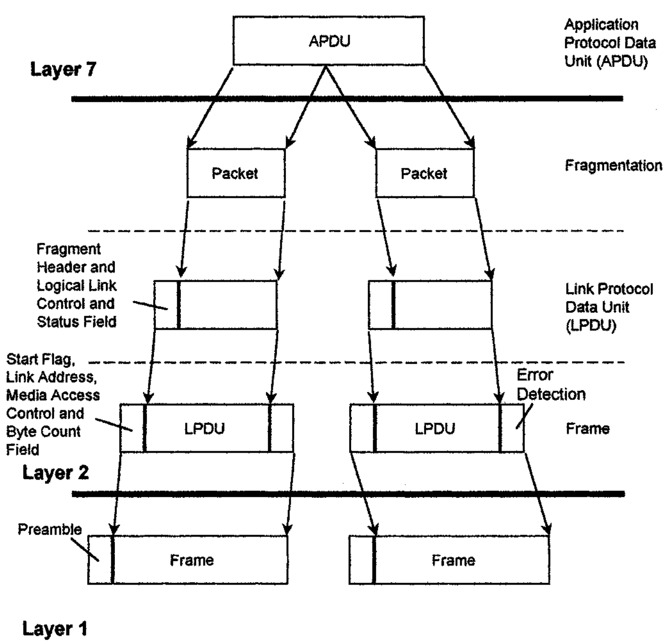

FIG. 2 Generic Encapsulation Process

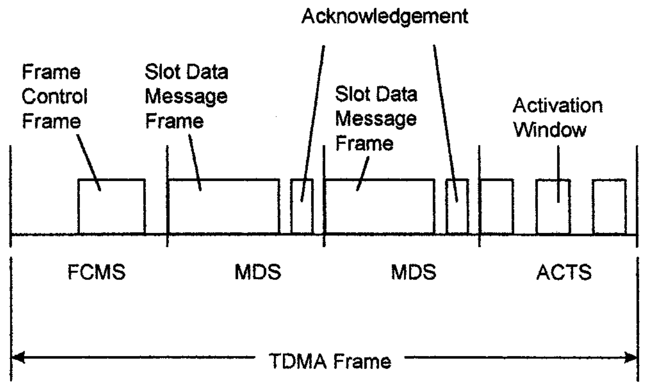

FIG. 3 Sample TDMA Frame Defining Synchronous Mode Terminology

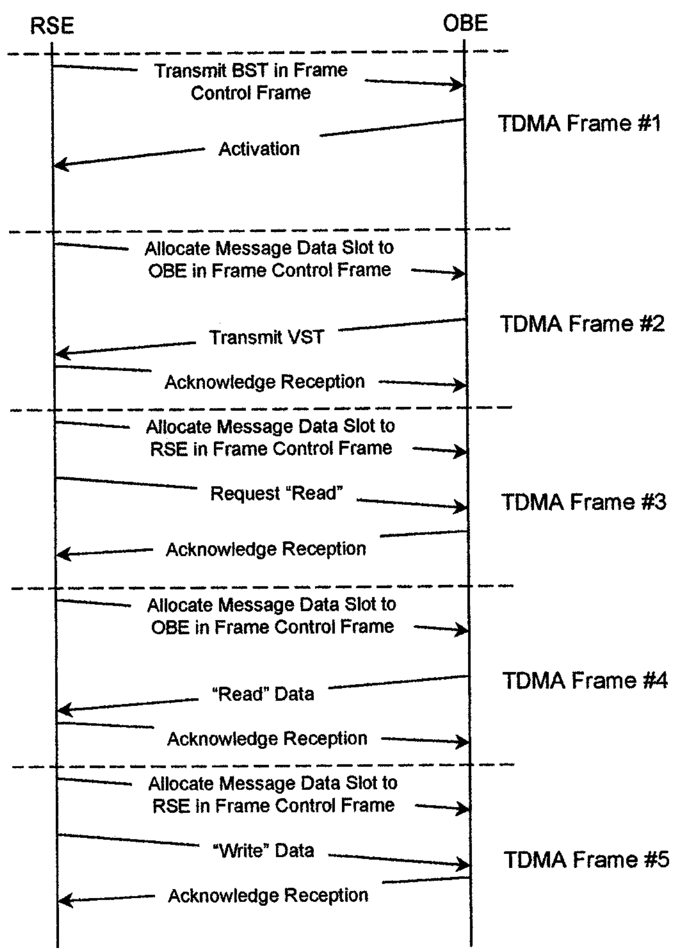

FIG. 4 Sample Read/Write Operation in Synchronous Mode

OBE to support a read in TDMA Frame #3. In TDMA Frame #4, the frame control frame designates an uplink message data slot to read the data. In TDMA Frame #5, the frame control frame designates a downlink message data slot to write data to the OBE. A corresponding acknowledgement is transmitted by the OBE.

1.2.5 In the asynchronous mode, communications with an OBE is always initiated with a frame control frame which is regularly broadcast by the RSE. Immediately following the frame control frame are a series of activation windows. The timing and structure of the frame control frame and activation windows can be made common to both synchronous and asynchronous operations (to minimize the differences between the two modes). It is expected that the frame control frame and the activation windows will be transmitted (or time allocated) periodically so that the RSE can poll its read zone for OBEs. When an OBE successfully activates, the RSE discontinues transmissions of the frame control frame to establish private communications with the OBE. These communications can occur asynchronously, that is, without a TDMA frame dividing time into slots. In addition, the specific sequence of frames transmitted is dependent entirely on the application layer. Once the private communications is completed, the RSE would then continue to poll using the frame control frame and activation windows. Note that opportunities to transmit on the downlink and uplink in the asynchronous mode are defined by windows which provide constraints on the start and end times for any frame transmissions. An activation window is a special case of an uplink window.

1.2.6 As above, assuming link establishment requires the transmission of a beacon service table (BST) from the RSE and negotiation of link parameters using a vehicle service table (VST), Fig. 5 provides an example of a typical read/write operation in asynchronous operation.

1.2.7 Like the synchronous mode, the OBE receives the BST from the RSE and attempts to activate. The activation frame is transmitted in activation windows that immediately follow the frame control frame. Once the activation is established, the RSE commands the OBE to transmit a VST and allocates an uplink window for the OBE to transmit the VST. After the VST is received, the RSE commands the OBE to support a read and allocates an uplink window for the OBE to transmit the read response. The OBE transmits the data. Then, the RSE writes data to the OBE and receives a reply that the write was successfully completed.

NOTE 1—Provisional Standards require only subcommittee consensus and are published for a limited time of two years. The provisional process was used because it is anticipated that the United States Department of Transportation will be referring to this provisional specification in their rule making.

2. Referenced Documents

2.1 This provisional specification incorporates by dated and updated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For data references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For updated references the latest of

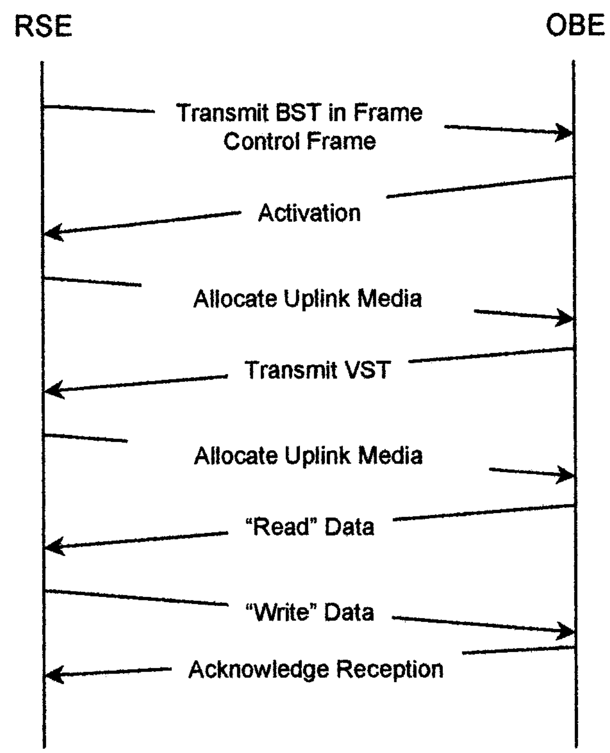

FIG. 5 Sample Read/Write Operation in Asynchronous Mode

the publication referred to applies.

2.2 *ASTM Standards:*

PS 111 DSRC Physical Layer Using Microwave in the 902 to 928 MHz Band[3]

2.3 *ISO and CCITT Standards:*

ISO 4335 : 1987 Information Processing Systems, Data Communications, High-Level Data Link Control Elements of Procedures[2]

ISO 7498 : 1984 Information Technology - Open Systems Interconnection - Basic Reference Model: The Basic Reference Model[2]

ISO 7809 : 1984 Information Processing Systems, Data Communications, High-Level Data Link Control Procedures, Consolidation of Classes of Procedures[2]

ISO 8802-2 : 1989 Local Area Networks - Part 2: Logical Link Control; ISO 8802-2 : 1989, Local Area Networks - Part 2: Logical Link Control, ADDENDUM 2: Acknowledged Connectionless-Mode Service and Protocol, Type 3 Operation[2]

ISO IS 3309 : 1984 Information Processing Systems - Data Communication — High-Level Data Link Control Procedures - Frame Structure[2]

ISO TC204 WG15 Japan Data Link Layer PreStandard of DSRC Draft (version 0.3)[2]

CCITT Recom. X.25 Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Terminals Operating in the Packet Mode and Connected to Public Data Networks by Dedicated Circuit[2]

[3] *Annual Book of ASTM Standards*, Vol 04.03.

CCITT Recom. X.200 Reference Model on Open Systems Interconnection for CCITT Applications[2]

2.4 *IEEE Standard:*

IEEE P1455 DSRC Application Layer[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *acknowledgement*—a frame, generated by the data link layer in response to a transmission, indicating that a frame, with a valid CRC, was received.

3.1.2 *activation window*—a period of time allocated by a frame control frame during which an OBE can transmit an activation frame to establish a communication session. The window will typically consist of guard times for transmit/receive switching, clock inaccuracies and the frame duration.

3.1.3 *downlink*—communication channel on which the RSE transmits its information to the OBE.

3.1.4 *frame*—the frame may be composed of a start flag (for frame synchronization), link address, MAC field, byte count, LPDU and CRC. All transmissions from either the OBE or RSE shall consist of a preamble (defined in Layer 1) and a frame.

3.1.5 *link address*—the link address identifies the specific access point that the OBE and RSE share in order to transfer commands and data.

3.1.6 *packet*—a field in a frame. It will consist of an APDU, if the APDU can be transmitted completely in one frame. However, it the APDU cannot be transmitted completely in one frame, then the packet will consist of a fragment of the APDU.

3.1.7 *reserved*—when a bit or bit field is reserved, it is reserved for future revisions of this provisional specification and shall not be used except as defined in this provisional specification.

3.1.8 *slot*—in synchronous mode, a slot refers to a fixed period of time for which media is allocated for either control, data transfer or activation.

3.1.9 *TDMA frame*—the TDMA Frame is a collection of up to seven contiguous slots during which frame control, data communications and activations will occur. The sequence of frame control, data communications and activations is continuously repeated and thus defines the synchronous data link layer service.

3.1.10 *uplink*—communication channel on which the OBE transmits its information to the RSE.

3.2 *Abbreviations:*

3.2.1 *ACPI*—activation possibility identifier.

3.2.2 *APDU*—application protocol data unit.

3.2.3 *BST*—beacon service table.

3.2.4 *CI*—control information.

3.2.5 *CM*—communications media.

3.2.6 *CRC*—cyclic redundancy check.

3.2.7 *DSRC*—dedicated short range communication.

3.2.8 *FSI*—frame structure identifier.

3.2.9 *LLC*—logical link control.

3.2.10 *LPDU*—logical link control protocol data unit.

3.2.11 *LSDU*—link service data unit.

3.2.12 *MAC*—media access control.

3.2.13 *MDS*—message data slot.

3.2.14 *MSB*—most significant bit.

3.2.15 *NOS*—number of slots.

3.2.16 *OBE*—on-board equipment.

3.2.17 *PDU*—protocol data unit.

3.2.18 *RSE*—roadside equipment.

3.2.19 *SAP*—service access point.

3.2.20 *SAT*—slot allocation table.

3.2.21 *SCI*—slot control identifier.

3.2.22 *TDMA*—time division multiple access.

3.2.23 *UI*—unnumbered information.

3.2.24 *VST*—vehicle service table.

4. Frame Format

4.1 *Overview*:

4.1.1 As discussed in Section 1, a frame is the result of encapsulation of a packet (which is either an APDU or a fragment of an APDU). All the fields that typically compose a frame are shown in Fig. 6. However, there are a number of exceptions to the generic frame structure including polling messages and acknowledgements.

4.1.2 In this section, each field in the frame is specified (including exceptions to the generic encapsulation and frame structure). Section 5 describes how these frames are used to poll, activate and transfer data.

4.2 *Field Definitions*—The following subsections describe specific bit values for the fields in a frame. Note that the start flag, link address, MAC field, byte count, fragment header, LLC and status field, and packet shall be transmitted most significant bit (MSB) first starting with the start flag's most significant byte. The CRC coefficient of the highest term shall be transmitted first.

4.2.1 *Start Flag*—All data frames shall start with a 16-bit start flag sequence. This flag is used to achieve frame synchronization. The start flag sequence is $8D7E_{16}$ (1000 1101 0111 1110 B).

4.2.2 *Link Address*:

4.2.2.1 The link address field shall contain a 32 bit sequence that identifies a specific connection between the RSE and OBE. The connection can be defined as either a private transmission between the RSE and a single OBE, or broadcast (one RSE to all OBEs within the beacon's field of view). The private link address shall be selected at random by the OBE Layer 7. If the random calculation to select a private link address results in the broadcast address, then a new private link address shall be generated. The address generation technique is not meant to be defined by any document and is left to the manufacturer. This standard does not provide any provisions to prevent duplicate link addresses to occur in the RSE's field of view.

4.2.2.2 Specific link address field formats are listed below.

Start Flag	Link Address	MAC Field	Byte Count	Fragment Header	Logical Link Control and Status	Packet	CRC

FIG. 6 Generic Frame Structure

[4] Available from The Institute of Electrical and Electronics Engineers, Inc., 345 E. 47th Street, NY, NY 10017.

Broadcast	0111 1100 1101 0010 1101 1000 0001 0101
Private (that is, address for point-to-point data exchange)	xxxx xxx0 xxxx xxx0 xxxx xxx0 xxxx xxx1 (x - don't care)

4.2.2.3 Note that the link address field is not used in some types of synchronous frames. Also note that the OBE shall save the private address and the last 8 bits of the Beacon ID used in a communication session. When an OBE starts a new communication session, it shall compare the last 8 bits of the beacon ID with the beacon ID saved from the previous communication session. If the beacon IDs are identical, it will use the previous private address and will not select a new address.

4.2.3 *MAC Field*—The MAC field is an eight-bit sequence transmitted in every frame. Specific bit definitions are listed in Table 1 and described below for all frames.

4.2.4 *Byte Count*:

4.2.4.1 The byte count field shall be an 8-bit sequence composed of a 7-bit byte count and the most significant bit Reserved. (The reserved bit should be set to 0.) In all frames (except the Frame Control Frame) the 7-bit byte count shall indicate the length of the packet in octet steps for the purposes of determining the length of the entire frame. A count of 000 0000 B corresponds to zero bytes while a count of 100 0000 B corresponds to 64 bytes. An RSE or OBE is only required to support five packet lengths, which are 0, 128, 256, 384 and 512 bits; however, as an option, the byte count field shall support up to 64 protocol data unit field lengths. Note that if the length of a packet defined by the byte count is greater than the data to be conveyed by the packet, then the data will be padded with zeros to the packet length.

4.2.4.2 For a Frame Control Frame, the byte count field shall indicate the length of the FSI, SAT and packet fields in octet steps.

4.2.5 *Fragment Header*:

4.2.5.1 Compliant devices that support application PDUs greater than 512 bits shall provide a fragmentation/defragmentation capability. Any APDU less than or equal to 512 bits shall be transmitted using a frame of sufficient length to avoid fragmentation, that is, fragmentation shall not be used for APDUs <= 512 bits.

4.2.5.2 The field shall be an 8-bit sequence, which counts down the packet sequence number. Therefore, the first fragment shall always have a header indicating the total number of fragments to be transmitted. This field, when combined with the byte count field, limit the size of the APDU to a maximum of two hundred fifty-six 512-bit packets.

4.2.6 *Logical Link Control and Status*:

4.2.6.1 The LLC field is an 8-bit sequence used primarily to support acknowledgements. Specific bit allocations are provided in Section 6.

4.2.7 *Packet*—This field will be composed of an APDU or a fragment of an APDU. The packet field length shall be defined by section 4.2.4. The specification of the APDUs is described in the IEEE P1455 Layer 7 Standard.

4.2.8 *Cyclic Redundancy Check*:

4.2.8.1 All data frames shall include a 16-bit Cyclic Redundancy Check (CRC) sequence for error detection purposes. All fields following the start flag shall be included in the calculation of the CRC.

4.2.8.2 The CRC shall be compliant with 16-bit frame checking sequence as defined in ISO 3309 (clause 3.6.2). The generator polynomial shall be $X^{16} + X^{12} + X^5 + 1$, and the initial value used shall be $FFFF_{16}$. The ones complement of the resulting remainder shall be transmitted as the 16-bit CRC.

4.2.9 *Frame Validity*—A frame shall be considered valid if it contains:

4.2.9.1 Valid start flag,

4.2.9.2 Valid CRC,

4.2.9.3 Valid MAC field,

4.2.9.4 Frame length that is an integer number of bytes, and

4.2.9.5 Valid link address field (if appropriate).

TABLE 1 MAC Field Bit Definitions

	7[A]	6[B]	5[C]	4[D]	3[E]	2[F]	1[G]	0[H]
	MSB							LSB
	Ack	First Packet	Reserved, set to 0	Sequence Bit	Command/ Response	Media Allocation	Uplink or Downlink	LPDU Existence
Bit Label	K	F		S	C/R	A-Downlink R-Uplink	D	L
Downlink	0 - ACK 1 - NACK	0 - not first packet 1 - first packet	0	0/1 - MAC Sequence Bit	0 - Command LPDU 1 - Response LPDU	0 - no media allocated 1 - media allocated	0	0 - No LPDU 1 - LPDU Follows
Uplink	0 - ACK 1 - NACK	0 - not first packet 1 - first packet	0	0/1 - MAC Sequence Bit	0 - Command LPDU 1 - Response LPDU	0 - no media requested 1 - media requested	1	0 - No LPDU 1 - LPDU Follows

[A] Bit 7 - in an acknowledgement frame, the bit shall be set to 1 if a frame with an invalid CRC is received. Otherwise, this bit shall be set to 0. In data message frames, the bit shall be set to 0 to request that the receipt of this frame be acknowledged. Otherwise, this bit shall be set to 1. In all other frames, this bit shall be set to 0.

[B] Bit 6 - when bit is set to 1, the frame contains the first packet of an APDU that has been fragmented. Otherwise, the bit shall be set to 0.

[C] Bit 5 - reserved.

[D] Bit 4 - The first time a data packet is transmitted to or from a new private link address, the bit is set to 0. For each subsequent data packet transmission using that private link address, the bit shall toggle, except when a retransmission is required. If retransmission is required, the bit shall not toggle. Uplink and downlink S bits toggle independently. For global addressed messages, the S bit toggles but has no predefined initial state.

[E] Bit 3 - when the LPDU existence bit (bit 0) is set to 1, then this bit indicates if the LPDU is command or response

[F] Bit 2 - on the downlink, indicates that the OBE can transmit; on the uplink, indicates that the OBE is requesting the opportunity to transmit (during normal activation, this bit is set to 0. If there is a reactivation using the same private link address, this bit is set to 1)

[G] Bit 1 - uplink or downlink transmission

[H] Bit 0 - when bit is set to 1, frame includes a byte count field, fragment header field, logical link control and status field, and possibly a fragment header and a packet.

5. Medium Access Control (MAC)

5.1 The medium access control sublayer can operate in two different half-duplex modes: synchronous and asynchronous time division multiple access. The preferred mode of operation will be indicated by the application layer residing in the RSE and transmitted to the OBE in the frame control PDU. Note that the OBE shall be able to support additional MAC functions not identified in this standard; however, the RSE shall not be required to support any additional functionality.

5.1.1 *Synchronous MAC*:

5.1.1.1 In the synchronous mode, all communications shall be based upon a continuously repeated TDMA frame. The TDMA frame is composed of up to seven contiguous time slots. The first slot in every TDMA frame is a frame control message slot (FCMS). This slot contains a frame control frame, which is a downlink broadcast from the RSE that allocates the remaining slots in the TDMA frame to data transfer or activation. A message data slot (MDS) is used to transfer data in either uplink or downlink. The MDS allocates time for both a slot data frame and a corresponding acknowledgement. (Transmission of the acknowledgement is an option, which is requested in the slot data frame.) The activation slot (ACTS) consists of a series of activation windows which permit an OBE to request a private communications channel with the RSE. Fig. 7 provides an example of the sequence of frame transmissions and slots in synchronous mode.

5.1.1.2 Note that if an OBE is allocated an MDS in a frame control frame that also allocates an MDS to the global address, the OBE shall only be required to perform processing associated with the private allocation. If possible, the OBE may also perform processing associated with the global allocation.

5.2 *Frame Description*—In this subsection, all frames used in the synchronous mode are described.

5.2.1 *Frame Control Frame*:

5.2.1.1 The frame control frame is a uniquely structured frame used to control the TDMA frame configuration (however, in the asynchronous mode, it is only used for polling as described in 5.2). It is unique because there are two fields that are inserted between the LLC and APDU field. These two fields indicate the TDMA frame configuration. They are the Frame Structure Identifier (FSI) and the Slot Allocation Table (SAT) as shown in Fig. 8. The FSI Field indicates the number of slots that can be controlled by the SAT. In the synchronous mode,

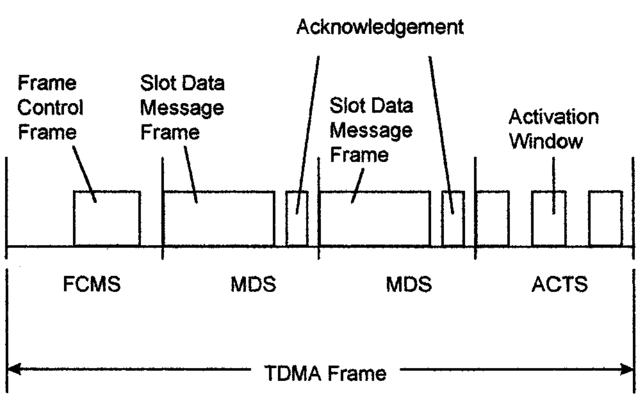

FIG. 7 Example of a Frame Transmission Sequence in Synchronous Mode

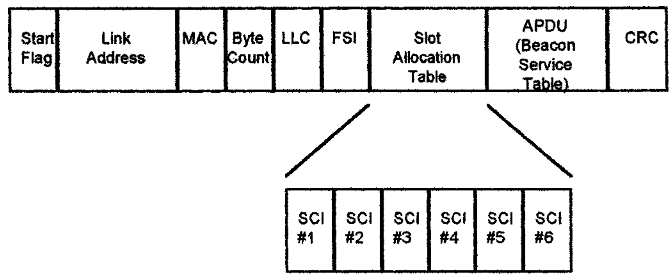

FIG. 8 Sample Frame Control Frame

one, three or six slots can be controlled by the SAT. The SAT consists of either one, three or six Slot Control Identifier (SCI) fields which allocate specific link addresses and frame types to a slot.

5.2.1.2 The specific bit definitions for the synchronous mode frame control frame shall be defined by Table 2.

5.2.2 *Frame Structure Identifier*:

5.2.2.1 Fig. 9 indicates the FSI bit allocations. The communication mode (CM) subfield is provided to permit future growth which would allow the RSE to operate an uplink and downlink channel simultaneously (full duplex); however, the OBE would continue to operate in half-duplex. This bit shall be set to 1 for RSE half-duplex operation. The number of slots (NOS) subfield indicates the number of available slot fields. Table 3 describes the valid bit combinations for the number of slots field.

5.2.2.2 The mode bit identifies the MAC mode. For synchronous mode operation, the mode bit shall be set to 1.

5.2.2.3 The slot size field indicates the duration of every slot allocated by the slot allocation table. The enumerated list of slot sizes is contained in Table 4.

5.2.3 *Slot Allocation Table*—The SAT consists of a series of Slot Control Identifier fields. Each field configures a specific slot and consists of a link address and control information identifier (CI) sub-field as shown in Fig. 10. The position of the SCI field in the SAT indicates its position within the TDMA frame (following the frame control slot). The link address subfield is 32-bits long and is used to allocate that slot to a specific link address. However, the global address is used for broadcast messages or for slots allocated to activation. The CI subfield specifies the type of slot.

5.2.3.1 Table 5 illustrates specific bit allocations for each of the four types of CI sub-fields. The slot identifier field indicates whether the slot will be a MDS, ACTS, an Empty Slot or an Idle Signal Slot. The empty slot can be used to make one of the slots allocated in the SAT inactive. For example, one method of allocating five slots after the frame control frame is to use a six slot SAT, but make one slot empty. The idle signal slot shall indicate that all 1's will be transmitted during the time period when an SDM would normally be transmitted in a MDS. Table 6 lists the combination of frames transmitted for each slot identifier.

5.2.3.2 The direction bit indicates the direction of transmission of the private message frame. If the message is transmitted from the OBE to the RSE, then the direction bit shall be set to 1. If the message is transmitted from the RSE to the OBE, then the direction bit shall be set to 0.

5.2.3.3 The activation type subfield indicates the number of

TABLE 2 Frame Control Frame Bit Definitions

Layer 1 Preamble	Start Flag	Link Address	MAC Field	Byte Count	LLC	FSI	SAT	APDU	CRC
8 bits	8D7E$_{16}$	000000FF$_{16}$	1010 0000	8 bits[A]	8 bits (see section 6)	See 5.2.2 and 5.2.3		BST	16 bits (see 4.2.7)

[A]not limited to the step sizes defined in section 4.2.4, includes FSI, SAT and APDU

Bit	0	1	2	3	4	5	6	7
Allocation	CM	Number of slots			Mode Bit	Slot Size		

FIG. 9 Frame Structure Identifier SubField Format

TABLE 3 Number of Slots Sub-field Valid Bit Combinations

Number of Slots (Size of the SAT)	b1	b2	b3
1	0	0	0
Reserved	1	0	0
3	0	1	0
Reserved	1	1	0
Reserved	0	0	1
6	1	0	1
Reserved	0	1	1
Reserved	1	1	1

TABLE 4 Slot Sizes

Bit Sequence - b5, b6, b7 (in Hex)	Slot Size (in bits)
0	Not used in this mode
1	448
2	700
3 to 7	Reserved

Link Address	Control Information Identifier

FIG. 10 Slot Control Identifier Field (Single Entry in a Slot Allocation Table)

activation windows allocated to the activation slot. Table 7 contains an enumerated list of activation window allocations.

5.2.3.4 The activation possibility identifier (ACPI) bit indicates if the RSE will permit the OBE to attempt to activate. If activation is prohibited, then the ACPI bit shall be set to 0. Otherwise, the ACPI bit shall be set to 1.

5.2.3.5 The activation probability subfield reduces the number of activation attempts to prevent excessive link entry attempts. The number of activation attempts will be modified by the activation probability. Thus, if b6 and b7 are set to 1, the tag will only attempt to activate during 50 % of the opportunities. The specific bit allocation is indicated in Table 8.

5.2.4 *Activation Frame*:

5.2.4.1 All activation frames transmitted in synchronous mode shall be defined by Table 9. Note that this field definition is the same as the asynchronous mode activation frame which is defined in 5.2.

5.2.5 *Slot Data Message Frame*:

5.2.5.1 All UL and DL SDM frames transmitted in synchronous mode shall be defined by Table 10. The SDM frames shall have all the fields defined in the generic frame (and the Data Message frame defined in 5.4) except for the link address.

5.2.5.2 Also note that the S bit shall be set to 0 during the first transmission of an SDM to/from a private link address. This bit shall toggle in all subsequent SDM transmissions in the same direction assuming valid frames are received. If a negative or no acknowledgement is received, then the previous SDM shall be transmitted with the same S bit.

5.2.6 *Acknowledgement Frame*:

5.2.6.1 All UL and DL acknowledgement frames transmitted to synchronous mode shall be defined by Table 11. If the K bit is 1, this shall indicate that the corresponding SDM frame was not a valid frame because it was not correctly delimited by a start flag as defined in 4.2 or did not have a valid CRC. If the K bit is 0, this shall indicate that the corresponding SDM frame was correctly delimited by a start flag and had a valid CRC.

5.2.6.2 For each SDM transmitted, the S bit in the corresponding acknowledgement frame shall be toggled from the S bit in the SDM if the SDM frame was valid. Thus, the S bit in the acknowledgement frame represents the state of the S bit in the next SDM to be transmitted to/from that private link address.

5.3 *Frame Timing*:

5.3.1 Table 12 summarizes the frame sizes for each of the types of synchronous frames.

5.3.2 Fig. 11 identifies the guard time parameters for the synchronous mode.

5.3.3 Tables 13 and 14 indicate the specific values for each guard time parameter for 448 bit and 700 bit slots, respectively. The RSE and OBE receiver shall accommodate ± 2 bit timing tolerance over the entire TDMA frame. In addition, Tables 13 and 14 shall define all combinations of slot size, number of activation windows and number of slots that must be supported in synchronous mode. Note that TDMA frames composed of 448 bit slots shall use a packet field length of 256 bits in the slot data message frame. Similarly, TDMA frames composed of 700 bit slots shall use a packet field length of 512 bits in the slot data message frame.

5.3.4 Fig. 12 provides an example of a 448 and Fig. 13 provides an example of a 700 bit TDMA frame configuration.

5.4 *Asynchronous MAC*—In the asynchronous mode, after activation, frames used to control link operation or convey data are not transmitted in synchronized slots that are allocated by a frame control message. They are allocated as needed by the RSE. In this section, the frames used in the asynchronous mode are described and the timing restrictions are specified.

5.4.1 *Frame Description*:

5.4.1.1 *Frame Control Frame*—The frame control frame is a uniquely structured frame used to poll for OBEs (and define the TDMA frame configuration if operating in the synchronous mode as indicated in 5.1). It is unique because there are two fields that are inserted between the LLC and APDU field. These two fields indicate how media will be allocated. They are the Frame Structure Identifier (FSI) and the Slot Allocation Table (SAT) as shown in Fig. 14. The FSI Field indicates that the link

TABLE 5 Control Information Identifier SubField Format

Bit	0	1	2	3	4	5	6	7
Allocation								
	0	0	0	0	0	0	0	Up - 1 Down - 0
	Slot Identifier - MDS (Table 6)		Reserved					Direction
(a) Message Data Slot								
Bit	0	1	2	3	4	5	6	7
Allocation	1	1	See Table 7			Permission - 1 Inhibition - 0	See Table 8	
	Slot Identifier - ACTS (Table 6)		Number of Activation Windows			ACPI	Activation Probability	
(b) Activation Slot								
Bit	0	1	2	3	4	5	6	7
Allocation	1	0						
	Slot Identifier - Empty (Table 6)		Reserved					
(c) Empty Slot								
Bit	0	1	2	3	4	5	6	7
Allocation	0	1						
	Slot Identifier - Idle Signal (Table 6)		Reserved					
(d) Idle Signal Slot								

TABLE 6 Slot Identifier

b0	b1	Type Description
0	0	MDS
1	1	ACTS
1	0	Empty Slot
0	1	Idle Signal Slot

TABLE 7 Number of Activation Windows Per Activation Slot

Number of Windows	b2	b3	b4
3 windows	0	0	0
7 windows	1	0	0
Reserved	0	1	0
Reserved	1	1	0
Reserved	0	0	1
Reserved	1	0	1
Reserved	0	1	1
Reserved	1	1	1

TABLE 8 Activation Probability

b6	b7	Activations Attempted (%)
0	0	100
1	1	50
1	0	25
0	1	12.5

TABLE 9 Activation Frame Field Definition

Layer 1 Preamble	Start Flag	Link Address	MAC Field	CRC
8 bits	$8D7E_{16}$	32 bits (see 4.2.2)	01R0 0000	16 bits (see 4.2.7)

is operating asynchronously and thus there is only one slot that is controlled by the SAT. The SAT has only one Slot Control Identifier field.

5.4.1.2 The specific bit definitions for the asynchronous mode frame control frame shall be defined by Table 15.

5.4.1.3 *Frame Structure Identifier*—Fig. 15 indicates the FSI bit allocations. The communication mode (CM) subfield is provided to permit future growth which would allow the RSE to operate an uplink and downlink channel simultaneously (full duplex); however, the OBE would continue to operate in half-duplex. This bit shall be set to 1 for RSE half-duplex operation. The number of slots (NOS) subfield indicates the number of available slot fields. Table 16 describes the valid bit combinations for the number of slots field. In the asynchronous mode, only 1 slot shall be allocated.

5.4.1.4 The mode bit identifies the MAC mode. For asynchronous mode operation, the mode bit shall be set to 0.

5.4.1.5 The slot size field indicates the duration of every slot allocated by the slot allocation table. The enumerated list of slot sizes is contained in Table 17. In the asynchronous mode, the slot size is not explicitly defined. Therefore, Type ID 0 shall always be used in asynchronous mode. Refer to 5.4.4 for frame timing details.

5.4.1.6 *Slot Allocation Table*—The SAT shall consist of a single SCI field. The field configures the activation windows that follow the frame control frame. It consists of a link address and control information identifier (CI) subfield as shown in Fig. 16. The link address subfield is 32-bits long and contains the global address. The CI subfield shall indicate that activation windows will follow as shown in Table 18.

5.4.1.7 The activation type subfield indicates the number of activation windows allocated to the activation slot. Table 19 contains an enumerated list of activation window allocations. In the asynchronous mode, three activation windows are allocated by a frame control frame.

5.4.1.8 The activation possibility identifier (ACPI) bit indicates if the RSE will permit the OBE to attempt to activate. If activation is prohibited, then the ACPI bit shall be set to 0. Otherwise, the ACPI bit shall be set to 1.

5.4.2 *Activation Frame*—All activation frames transmitted in asynchronous mode shall be defined by Table 20. Note that this field definition is the same as the activation frame in the synchronous mode as defined in 5.1.

5.4.3 *Data Message Frame*—All UL and DL Data Message (DM) frames transmitted in asynchronous mode shall be defined by Table 21. It is the same as the SDM frame (defined in the synchronous mode only) with the addition of the link address field.

5.4.3.1 The DM frame shall be used to transfer data, acknowledge receipt of transmissions and allocate uplink media to the OBE. The specific function supported by a frame shall be determined from the MAC field. During data transfer,

TABLE 10 Slot Data Message Frame

Frame Type	Layer 1 Preamble	Start Flag	MAC Field	Byte Count	Fragment Header	LLC	Packet	CRC
DL SDM	8 bits	$8D7E_{16}$	10AC S0FK	8 bits (see 4.2.4)	8 bits (see 4.2.5)	8 bits (see section 6)	256 or 512 bits	16 bits (see 4.2.7)
UL SDM	8 bits	$8D7E_{16}$	11RC S0FK	8 bits (see 4.2.4)	8 bits (see 4.2.5)	8 bits (see section 6)	256 or 512 bits	16 bits (see 4.2.7)

TABLE 11 Acknowledgement Frame

Frame Type	Layer 1 Preamble	Start Flag	MAC Field	CRC
UL Ack	8 bits	$8D7E_{16}$	0101 S00K	16 bits (see 4.2.7)
DL Ack	8 bits	$8D7E_{16}$	0001 S00K	16 bits (see 4.2.7)

TABLE 12 Synchronous Frame Sizes

Frame Type	Size in Bits (Includes Preamble)
Frame Control (1 slot allocation)	256[A]
Frame Control (3 slot allocation)	336[A]
Frame Control (6 slot allocation)	456[A]
Activation	80
SDM (packet sizes: 256, 512)	328, 584[B]
Acknowledgement	48

[A]Based on a 112 bit BST (which is required for small read zone deployments).
[B]Includes fragment header.

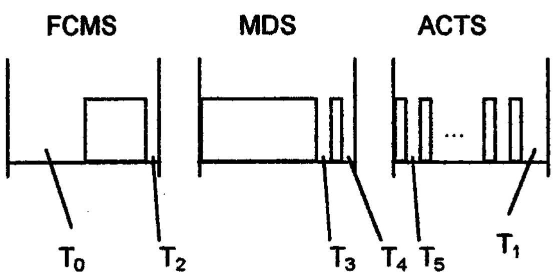

FIG. 11 Slot Guard Time Diagram

TABLE 13 Guard Time Measured in Bit Count for 448 Bit Slots

	Bit Count					
Number of Slots	1		3		6	
Number of Activation Windows	3	7	3	7	3	7
T_0[A]	112	N/A	32	N/A	N/A	N/A
T_1	184	N/A	184	N/A	N/A	N/A
T_2	80	N/A	80	N/A	N/A	N/A
T_3	47	N/A	47	N/A	N/A	N/A
T_4	25	N/A	25	N/A	N/A	N/A
T_5	8	N/A	8	N/A	N/A	N/A

[A]Based on Table 7

TABLE 14 Guard Time Measured in Bit Count for 700 Bit Slots

	Bit Count					
Number of Slots	1		3		6	
Number of Activation Windows	3	7	3	7	3	7
T_0[A]	N/A	364	N/A	284	N/A	164
T_1	N/A	92	N/A	92	N/A	92
T_2	N/A	80	N/A	80	N/A	80
T_3	N/A	43	N/A	43	N/A	43
T_4	N/A	25	N/A	25	N/A	25
T_5	N/A	8	N/A	8	N/A	8

[A]Based on Table 7

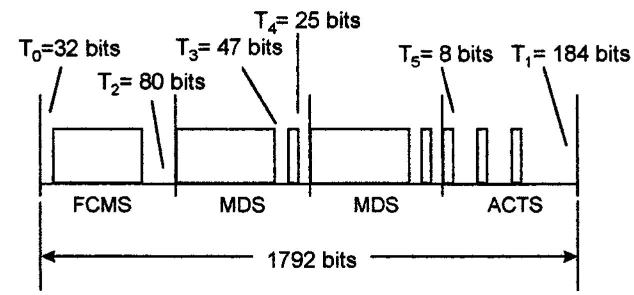

FIG. 12 Example of 448 Bit Slot Configuration

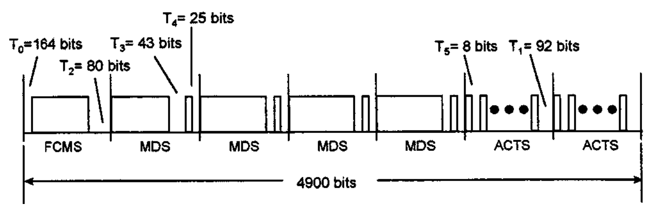

FIG. 13 Example of 700 Bit Slot Configuration

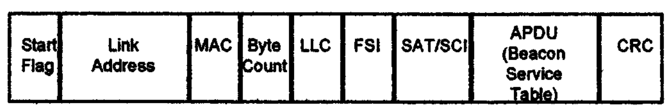

FIG. 14 Asynchronous Frame Control Frame

the L-bit of the MAC field shall be set to 1 and the S-bit of the MAC field shall toggle. If the DM frame should be acknowledged, then the K-bit of the MAC field shall be set to 0. If the DM frame is transmitted on the uplink and is requesting media, then the R-bit of the MAC field shall be set to 1.

5.4.3.2 In response to a request for acknowledgement, a DM frame shall be transmitted with the L-bit of the MAC field set to 0 and the K-bit of the MAC field set depending on the outcome of the frame validity check. In response to a request for media, a DM frame shall be transmitted with the L-bit of the MAC field set to 0 and the A-bit of the MAC field set depending on the decision to allocate media.

5.4.4 *Frame Timing*—For the purposes of specifying timing, a frame shall be defined as starting at the first bit of the preamble and ending at the last bit of the CRC or postamble (if it is transmitted). In addition, the opportunity to activate after a polling message shall be referred to as an activation window.

5.4.5 *Downlink Frames*:

5.4.5.1 Downlink frames include frame control, and data messages and private allocation frame types. A downlink frame shall start no earlier than 50 usecs after the end of an uplink frame transmission or the period of time during which an uplink transmission could have occurred (for example, an activation window). Figs. 17 and 18 provide examples of downlink frame timing.

5.4.5.2 In addition, a downlink frame shall be transmitted

TABLE 15 Frame Control Frame Bit Definitions

Layer 1 Preamble	Start Flag	Link Address	MAC Field	Byte Count	LLC	FSI	SAT	APDU	CRC
8 bits	$8D7E_{16}$	$000000FF_{16}$	1010 0000	8 bits	8 bits (see Section 6)	See 5.2.2 and 5.2.3		BST	16 bits (see 4.2.7)

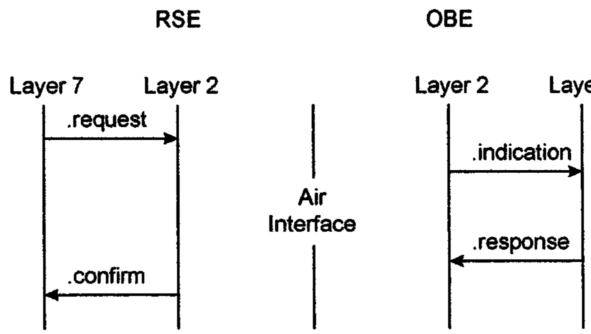

FIG. 15 Primitive Extension Naming Convention

TABLE 16 Number of Slots Sub-Field Valid Bit Combinations

Number of Slots (Size of the SAT)	b1	b2	b3
1	0	0	0
Reserved	1	0	0
Not used in this mode	0	1	0
Reserved	1	1	0
Reserved	0	0	1
Not used in this mode	1	0	1
Reserved	0	1	1
Reserved	1	1	1

TABLE 17 Slot Sizes

Type ID (in Hex)	Slot Size (in bits)
0	Undefined slot size
1	Not used in mode
2	Not used in mode
3 - F	Reserved

FIG. 16 Slot Control Identifier Field (Single Entry in a Slot Allocation Table)

no sooner than 50 usecs after another downlink frame. The capability to receive several consecutive downlink frames by one OBE is at the discretion of the implementor.

5.4.6 *Activation Windows*—Activation frames are sent in one of three activation windows following a polling frame as shown in Fig. 19. The first activation window shall occur 160 usec after the polling frame. Subsequent activation windows shall follow immediately after the last window. Each window shall last for 176 usecs. The transmission of the start of the first bit of the activation frame preamble in an activation window shall start before 16 usecs after the start of that window.

5.4.7 *Non-Activation Uplink Frames*—Non-activation uplink frames shall not start until at least 160 usecs after the end of the downlink frame allocating the uplink transmission (Fig. 20). In addition, if the OBE does not begin to respond within 480 usecs of the end of the downlink frame (allocating the uplink transmission), then the opportunity for the OBE to respond will be cancelled. A new downlink frame can then be transmitted as described in 5.2.2.1.

6. Logical Link Control

6.1 The LLC sublayer supports two types of services: no response (designated UI in this section) and response expected (designated AC in this section). When the no response service is employed, the RSE transmits information to the OBE and does not expect any information to be returned. This would typically be used in broadcast applications. When the response expected service is employed, the RSE shall allocate media in order to obtain information transmitted back from the OBE. This information could be the response to a read command or confirmation that a write command was successful.

6.1.1 Both the UI and AC service are described in the following sections.

6.2 *No Response Service*:

6.2.1 The LLC service, which does not expect a response from the data link layer, makes use of the UI command. UI commands can be used on the downlink and uplink transmissions. On the downlink, UI commands are used with the broadcast link address or a private link address. On the uplink, the UI command is used with a private link address. When using a UI command, the C/R bit of the MAC field shall indicate command. The LLC control field bit values shall be set according to Table 22.

6.2.2 The M bits are not defined in this standard but are set to 0 in Table 22 to support harmonization with other international standards.

6.2.3 The p bit is called the Poll bit. It indicates whether an application layer response is requested to be returned on the uplink. This bit shall be set to 0, indicating no response service.

6.3 *Response Service*—The LLC service in which an RSE expects a response from the data link layer of the OBE makes use of the AC command. This command generates an AC response that is transmitted by the OBE on the uplink.

6.3.1 *Downlink*:

6.3.1.1 The AC command, which is always used with a private link address, always requires a response by the OBE data link layer. When this command is used, the C/R bit of MAC control field is set to 0 to indicate Command. The LLC control field bit values shall be set according to Table 23.

6.3.1.2 The p bit is called the Poll bit, indicating whether an application layer response is requested to be returned on the uplink or not, see 6.2.2.

6.3.1.3 Bits 0, 1, 2, 4, and 5 (which are labeled M) have been fixed to support harmonization with international standards.

6.3.2 *Uplink*:

6.3.2.1 The acknowledged command always requires a response by the data link layer. Each AC commands on the

TABLE 18 Control Information Identifier SubField Format for Asynchronous Mode

Bit	0	1	2	3	4	5	6	7
Allocation	1	1	See Table 19			Permission - 1 Inhibition - 0	0	0
	Slot Identifier - Activation		Number of Activation Windows			ACPI	Activation Probability-100 %	

TABLE 19 Number of Activation Windows Following Frame Control

Number of Windows	b2	b3	b4
3 windows	0	0	0
Not used in this mode	1	0	0
Reserved	0	1	0
Reserved	1	1	0
Reserved	0	0	1
Reserved	1	0	1
Reserved	0	1	1
Reserved	1	1	1

TABLE 20 Activation Frame Field Definition

Layer 1 Preamble	Start Flag	Link Address	MAC Field	CRC
8 bits	8D7E$_{16}$	32 bits (see 4.2.2)	0100 0000	16 bits (see 4.2.7)

downlink generates an AC response on the uplink.

6.3.2.2 LLC control field content for the response is ACn with f=0 or ACn with f=1 depending on whether an application layer response was requested. The C/R bit of the MAC field is set to 1 which indicates Response. The response field is illustrated in Table 24.

6.3.2.3 AC responses are always used with the private link address of the originator.

6.3.2.4 For an AC command ACn with p=0, the corresponding response shall be an ACn with f=0, with status bits set to 10_2 and no response LPDU information field. No response was requested. This command is used to pass application layer data to the OBE.

6.3.2.5 For an AC command ACn with p=1, the corresponding response shall be ACn with f=1. The response shall contain LLC status bits of 00_2 and an LPDU information field included if the processing of the application command resulted in the availability of an application response. The response shall have an LLC status field of 11_2 and no LPDU information field included if the response to the application command is not available yet. This command is used to pass application layer commands to the OBE and the associated responses to the RSE.

7. Process Description

7.1 The process of initializing a link, transferring data, and recovering from errors is discussed in this section. The process can be divided into two components: the interface to the application layer and the specific MAC and LLC processes. The interface between the application layer and the data link layer is defined by a set of primitives. These primitives follow the naming convention illustrated in Fig. 15.

7.1.1 Each primitive will be associated with up to five parameters, which represent information that can be made available to the receiving layer. The five parameters are listed below:

7.1.1.1 *Link Address*—Identifies the specific connection between the RSE and OBE (format is described in 4.2.2).

7.1.1.2 *Control*—Information passed between layers in either the RSE or OBE that indicates specific options should be exercised (for example, request for acknowledged operation, repeat conditions); does not affect the air interface.

7.1.1.3 *Byte Count*—Indicates size of data, in number of bytes, being passed from Layer 7 to Layer 2.

7.1.1.4 *Data*—May be provided by passing the LSDU, or a pointer or other means.

7.1.1.5 *Status*—Indicates the success or failure of a previous associated action.

7.1.2 Note that all the primitives and processes are provided for illustrative purposes only. They do not define a testable interface between Layer 7 and Layer 2. It is expected that this interface will not be exposed and therefore, not testable. However, those elements that refer to the air interface shall be testable.

7.1.3 These primitives are discussed in this section along with the MAC and LLC processes that are combined to provide an overall Data Link Layer process description.

7.2 *Service Primitives*:

7.2.1 The service primitives defined in this standard are listed below and correspond directly to the list of services identified in the Application Layer Standard P1455. Additional detail on primitive data elements can be found in the P1455 Application Layer Standard.

DL_SEND_BST_RESPOND	DL_SEND_BST_RESPOND_REPEAT
DL_DATASEND_NORESPOND	DL_DATASEND_NORESPOND_REPEAT
DL_DATASEND_RESPOND	DL_DATASEND_RESPOND_REPEAT

7.2.1.1 The list of primitives can be grouped into pairs of primitives, a version in which the application layer is required to issue a primitive each time it attempts to transmit over the air interface (for example, DL_DATASEND_NORESPOND) and a version in which the data link layer will repeatedly transmit the data until the data is updated or it is instructed to stop (for example, DL_DATASEND_NORESPOND_REPEAT).

7.2.1.2 Table 25 indicates the relationship between the primitives and the MAC and LLC layers. Specifically, for each "primitive".request, a frame is transmitted with the following MAC and LLC field values.

7.2.2 *DL_SEND_BST_RESPOND*:

7.2.2.1 The DL_SEND_BST_RESPOND primitive is unique to the activation process. It is used when the RSE application layer controls the rate at which frame control frames are transmitted. In particular, every time the application layer issues a DL_SEND_BST_RESPOND.request, it results in transmission of a single frame control frame (that allocates some number of activation windows). In the synchronous mode, use of this primitive implies that a single TDMA frame is established every time a DL_SEND_BST_RESPOND.request is issued and therefore the primitive must be issued

TABLE 21 Data Message Frame

Frame Type	Layer 1 Preamble	Start Flag	Link Address	MAC Field[A]	Byte Count	Fragment Header	LLC	Packet	CRC
DL DM	8 bits	$8D7E_{16}$	32 bits (see 4.2.2)	L0AC S0FK	8 bits (see 4.2.4)	8 bits	8 bits (see 6.0)	up to 512 bits[B]	16 bits (see 4.2.7)
UL DM	8 bits	$8D7E_{16}$	32 bits (see 4.2.2)	L1RC S0FK	8 bits (see 4.2.4)	8 bits	8 bits (see 6.0)	up to 512 bits[B]	16 bits (see 4.2.7)

[A] C bit in the MAC field represents the C/R bit described in Table 1.
[B] Packet lengths may be 0, 128, 256, 384, or 512 bits long. See 4.2.4.

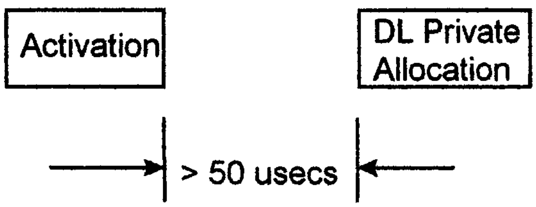

FIG. 17 Minimum Time Delay of Downlink Transmission after an Uplink Transmission

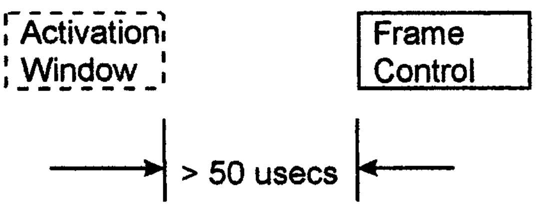

FIG. 18 Minimum Time Delay of Downlink Transmission after Uplink Transmission Opportunity

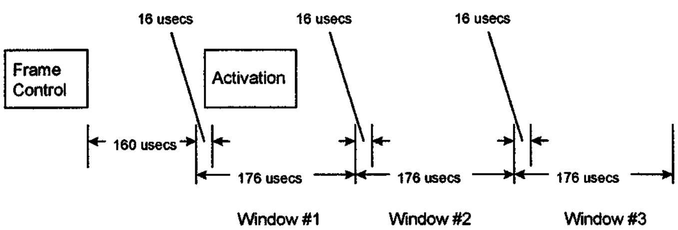

FIG. 19 Activation Window Timing

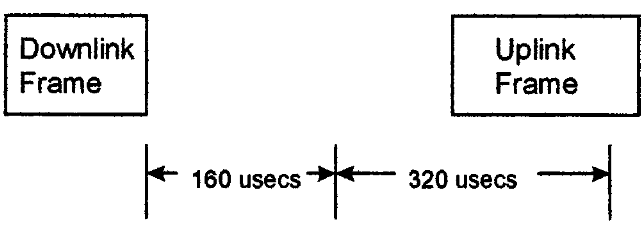

FIG. 20 Uplink Frame Timing after the Allocating Downlink Frame

TABLE 22 LLC Control Field for UI Commands

0	1	2	3	4	5	6	7	. . .	Bit Number
M	M	M	p	M	M	Res[A]	Res[A]	hex	Command
0	0	0	0	0	0	1	1	03	UI

[A] Res– Reserved bits

TABLE 23 LLC Control Field for AC Commands[A,B]

0	1	2	3	4	5	6	7	. . .	Bit Number
M	M	M	p	M	M	Res	Res	hex	Command
1	1	1	0	0	1	1	1	E7	ACn w/p=0
1	1	1	1	0	1	1	1	F7	ACn w/p=1

[A] The p bit is called the Poll bit, indicating whether an application layer response is requested to be returned on the uplink or not, see 6.2.2.1.
[B] Bits 0, 1, 2, 4, and 5 (which are labeled M) have been fixed to support harmonization with international standards.

TABLE 24 LLC Control Field for AC Responses[A]

0	1	2	3	4	5	6	7	. . .	Bit Number
M	M	M	f	M	M	Status	Status	Hex	Command
1	1	1	0	0	1	1	0	D6	ACn w/f=0
1	1	1	1	0	1	x	x	E4 or E7	ACn w/f=1

[A] Bits 0, 1, 2, 4, and 5 have been fixed to support harmonization with international standards.

TABLE 25 Relationship Between Primitives and MAC/LLC Sublayers

Primitive (.request)	MAC	LLC
DL_SEND_BST_RESPOND	1010 0000	0000 0011
DL_DATASEND_NORESPOND	100C S0FK	0000 0011
DL_DATASEND_RESPOND	100C S0FK	111p 0111

at the TDMA frame rate.

7.2.2.2 The activation process consists of broadcasting the BST (in a frame control frame) to all OBEs within the read zone and then allocating a series of activation windows that permit the OBE to activate. Once activated, the OBE is allocated media in order to transmit data (memory image). The type of data transmitted by the OBE is dictated by the BST (refer to IEEE P 1455 for details).

7.2.2.3 The DL_SEND_BST_RESPOND.request primitive is used by the RSE application layer to poll for OBEs. The parameters for this primitive are listed below:

```
DL_SEND_BST_RESPOND.request(
        link address (global),
        control,
        byte count,
        data (beacon service table)
        )
```

7.2.2.4 The DL_SEND_BST_RESPOND.indication primitive is used by the OBE data link layer to pass the BST to the OBE application layer. The parameters for this primitive are listed below:

```
DL_SEND_BST_RESPOND.indication(
        link address (global),
        data (beacon service table),
        status
        )
```

7.2.2.5 The DL_SEND_BST_RESPOND.response primitive is used by the OBE application layer to pass a memory image to the OBE data link layer. The parameters for this primitive are listed below:

```
DL_SEND_BST_RESPOND.response(
        link address,
        byte count,
```

data (vehicle service table or memory image),
status
)

7.2.2.6 The DL_SEND_BST_RESPOND.confirm primitive is used by the RSE data link layer to pass a memory image to the RSE application layer. The parameters for this primitive are listed below:

DL_SEND_BST_RESPOND.confirm(
link address,
data (vehicle service table or memory image),
status
)

7.2.2.7 Note that the DL_SEND_BST_RESPOND_REPEAT primitive is used when the application layer requires the data link to repeatedly transmit the frame control frame (and activation windows) with the same BST until another DL_SEND_BST_RESPOND_REPEAT.request is issued. This permits the data link to independently poll for new OBEs and minimizes the data traffic transmitted from the application layer to the data link layer (compared to the DL_SEND_BST_RESPOND primitive). The DL_SEND_BST_RESPOND_REPEAT primitive has the same format as the DL_SEND_BST_RESPOND primitive in the RSE. Since the OBE does not know whether the frame control frame was a result of the repeating primitive, the OBE will use DL_SEND_BST_RESPOND.indication and DL_SEND_BST_RESPOND.response for both the repeating and non-repeating versions of the primitive.

7.2.3 *DL_DATASEND_NORESPOND*:

7.2.3.1 The DL_DATASEND_NORESPOND primitive is used when the RSE application layer would like to transmit data to the OBE (for example, to write into memory that controls operation of an OBE feature). It does not expect a response.

7.2.3.2 The DL_DATASEND_NORESPOND.request primitive is used by the RSE application layer to initiate the process. The parameters for this primitive are listed below:

DL_DATASEND_NORESPOND.request(
link address,
control,
byte count,
data
)

7.2.3.3 The request for confirmation, contained in the control field, indicates that the RSE data link layer is expecting an acknowledgement from the data link layer to confirm delivery of the data.

7.2.3.4 The DL_DATASEND_NORESPOND.indication primitive is used by the OBE data link layer to pass the data to the OBE application layer. The parameters for this primitive are listed below:

DL_DATASEND_NORESPOND.indication(
link address,
data
)

7.2.3.5 The DL_DATASEND_NORESPOND.confirm primitive is used by the RSE data link layer to pass a confirmation to the RSE application layer. The parameters for this primitive are listed below:

DL_DATASEND_NORESPOND.confirm(
link address,
status
)

7.2.3.6 Note that the DL_DATASEND_NORESPOND_REPEAT primitive is used when the RSE application layer would like to transmit data (to write into memory that controls operation of an OBE feature, etc.) to OBEs repetitively. It does not expect a response. A typical application would be the broadcast of general-purpose traveller information. The DL_DATASEND_NORESPOND_REPEAT primitive has the same format as the DL_DATASEND_NORESPOND primitive in the RSE. Since the OBE does not know whether the frame was a result of the repeating primitive, the OBE will use DL_DATASEND_NORESPOND.indication for both the repeating and non-repeating versions of the primitive.

7.2.4 *DL_DATASEND_RESPOND*:

7.2.4.1 The DL_DATASEND_RESPOND primitive is used when the RSE application layer would like to transmit data and receive a response that originates from the OBE application layer. Examples include a write into memory with confirmation or a command to read a page of memory.

7.2.4.2 The DL_DATASEND_RESPOND.request primitive is used by the RSE application layer to initiate the process. The parameters for this primitive are listed below:

DL_DATASEND_RESPOND.request(
link address,
control,
byte count,
data
)

7.2.4.3 The DL_DATASEND_RESPOND.indication primitive is used by the OBE data link layer to pass the data to the OBE application layer. The parameters for this primitive are listed below:

DL_DATASEND_RESPOND.indication(
link address,
data
)

7.2.4.4 The DL_DATASEND_RESPOND.response primitive is used by the OBE application layer to pass the response data to the OBE data link layer. The parameters for this primitive are listed below:

DL_DATASEND_RESPOND.response(
link address,
byte count,
data,
status
)

7.2.4.5 The DL_DATASEND_RESPOND.confirm primitive is used by the RSE data link layer to pass the response data to the RSE application layer. The parameters for this primitive are listed below:

DL_DATASEND_RESPOND.confirm(
link address,
data,
status
)

7.2.4.6 Note that the DL_DATASEND_RESPOND_REPEAT primitive is used when the RSE application layer would like to transmit data to and receive a response from the

OBE application layer repetitively. A typical application would be the polling of a keyboard or SAE J-bus to determine when new data was present. The DL_DATASEND_RESPOND_REPEAT primitive has the same format as the DL_DATASEND_RESPOND primitive in the RSE. Since the OBE does not know whether the frame was a result of the repeating primitive, the OBE will use DL_DATASEND_RESPOND.indication and DL_DATASEND_RESPOND.confirm for both the repeating and non-repeating versions of the primitive.

7.3 *Data Link Layer Processes*:

7.3.1 The Data Link Layer processes are a combination of functions conducted at both the MAC and LLC levels. The specific process depends on the application layer function supported. They include initialization and data transfer. Initialization typically precedes data transfer when the RSE attempts to exchange data with a private link address. However, data may also be transferred from the RSE to OBEs using a broadcast (which does not require initialization).

7.3.1.1 Note that a state diagram accompanies the process descriptions in this section. These state diagrams illustrate typical operations; they are not meant to define all error conditions. A sample state diagram is illustrated in Fig. 21. It is assumed that all processes are initiated from the ready state and that transitions from any state to another state can only occur when the event conditions are satisfied. When an event occurs, an associated action may also be taken.

7.3.1.2 It is also assumed that an RSE or OBE may have concurrent processes executing at any specific instance in time. However, the discussions in this section do not explicitly describe concurrent RSE or OBE operations.

7.3.1.3 Finally, note that implicit to any action that includes the reception of a transmitted frame is a frame validity check using criteria defined in 4.2.9.

7.3.2 *Initialization*:

7.3.2.1 The first step in the initialization process is the RSE Application Layer issuing a DL_SEND_BST_RESPOND.request. This results in the RSE Data Link Layer broadcasting the initialization information (a BST transmitted in a frame control frame) to all OBEs within the read zone and then allocating a series of activation windows that permit the OBE to activate. Once activated, the OBE is allocated media in order to transmit data. The type of data transmitted by the OBE is dictated by the BST (refer to IEEE P 1455 for details). The process is illustrated in Fig. 22. Note that Fig. 22 indicates that an acknowledgement (represented by a dashed line) is transmitted by the RSE to the OBE. However, this acknowledgement only occurs in the synchronous mode or if the requested APDU must be fragmented. In addition to the acknowledgement, it is implied that an OBE, operating in synchronous mode, will continue to decode and provide the BST to Layer 7 every frame control frame regardless of state.

7.3.2.2 *RSE Initialization Process*—The state diagram for RSE initialization is depicted in Fig. 23.

7.3.2.3 *Ready State to Wait for Activation State*:

Current State:	Ready
Event:	RSE Layer 2 receives a DL_SEND_BST_RESPOND.request from the RSE Layer 7 (to transmit the BST)
Action:	Layer 2 will generate a frame control frame (which allocates activation windows) as specified in 5.2.1 and 5.4.1.1 and pass the frame to Layer 1. Control fields shall be set as follows: 1. Set the L and A bit of the MAC field to 1 (AO_{16}) as specified in Table 2 and Table 15 2. Set LLC field to 03_{16} as specified in 6.1.
Next State:	Wait for Activation

7.3.2.4 *Wait for Activation State to Ready State*:

Current State:	Wait for Activation
Event:	No activations were received during activation windows allocated by frame control frame.
Action:	Layer 2 will generate a DL_SEND_BST_RESPOND.confirm to Layer 7 with status field indicating that no valid activations were received during activation windows
Next State:	Ready

7.3.2.5 *Wait for Activation State to Wait for Data State*:

Current State:	Wait for Activation
Event:	A valid activation was received during activation windows allocated by the frame control frame.
Action:	Layer 2 will allocate media to the private link address contained within the activation. In the asynchronous mode, Layer 2 sends a data message frame that allocates media to the private link address as specified in 5.4.3. The L and A bit of the MAC field shall be set to 1 (AO_{16}). In the synchronous mode, Layer 2 sends a frame control frame allocating a MDS to the private link address in the next TDMA frame by placing the link address in the SAT as specified in 5.2.3.
Next State:	Wait for Data

7.3.2.6 *Wait for Data State back to Wait for Data State (CRC Fails)*:

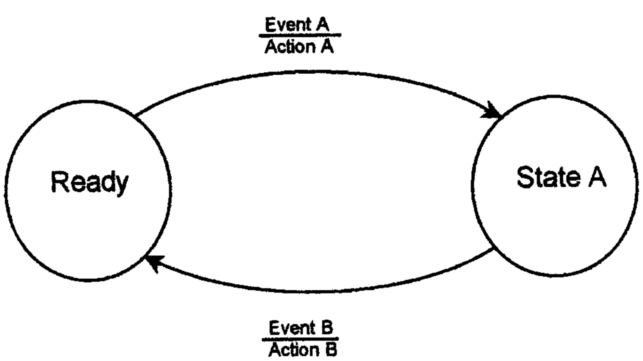

FIG. 21 Sample Process State Diagram

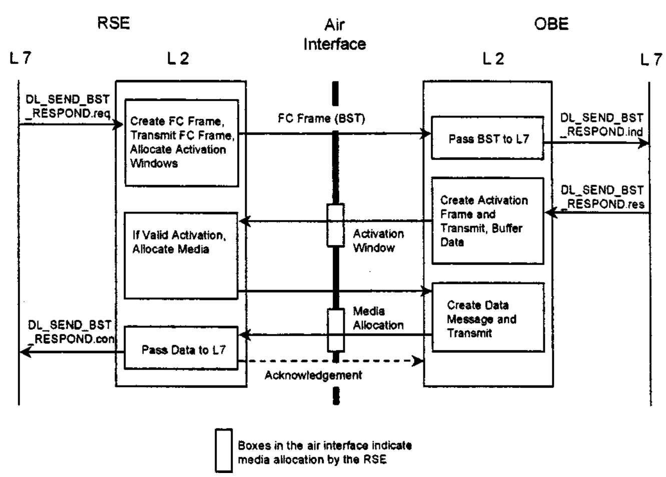

FIG. 22 Activation Process Overview

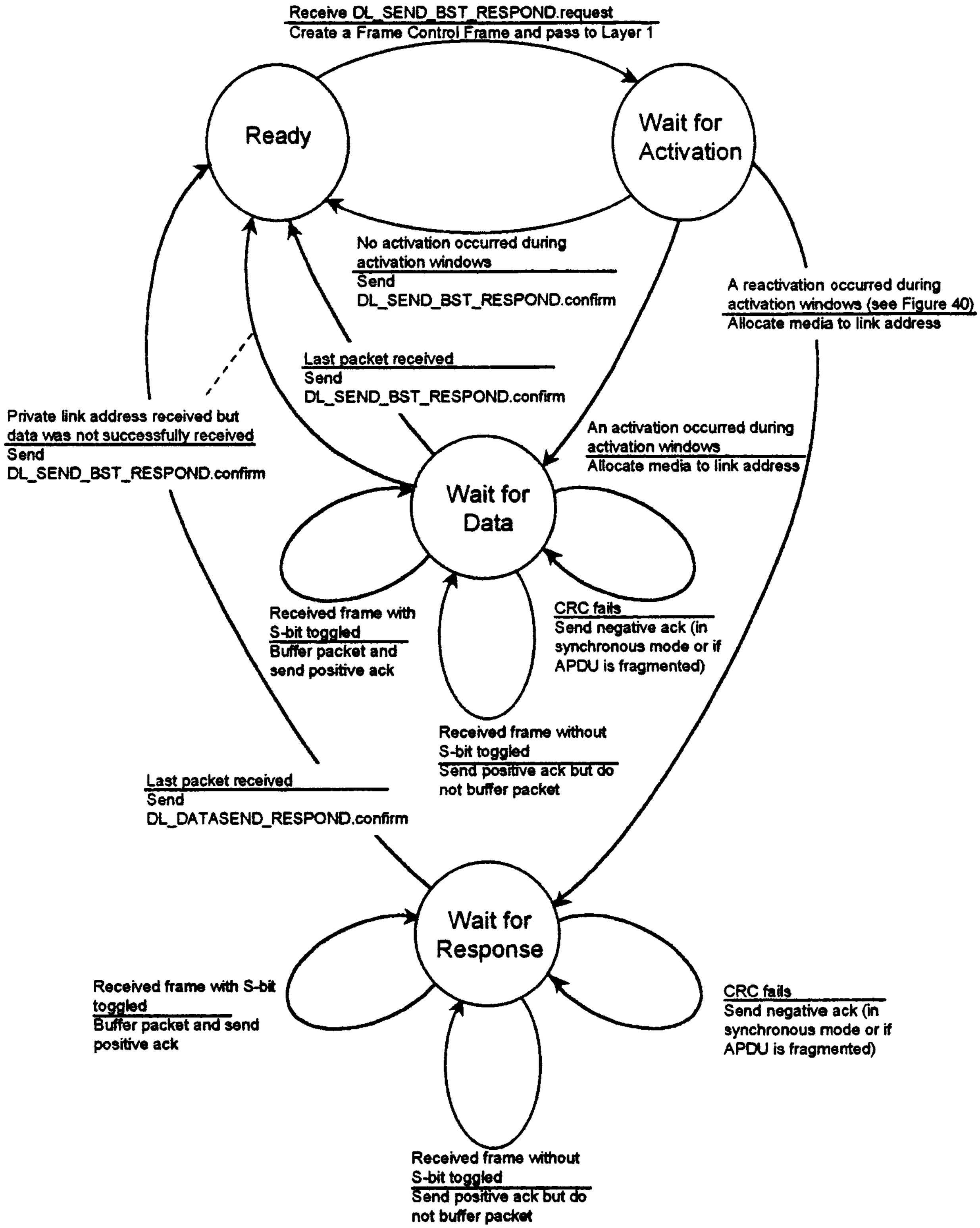

FIG. 23 RSE Initialization State Diagram

Current State: Wait for Response

Event: A frame is received but the CRC fails (in synchronous mode or if APDU is fragmented). Note that a retry count could be used to limit the number of consecutive failed transmission attempts. The threshold for the count is not defined in this provisional specification.

Action: Send a negative acknowledgement as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous) and allocate media for retransmission as in 7.3.2.5.

Next State: Wait for Response

7.3.2.7 *Wait for Data State Back to Wait for Data State (S-bit Untoggled)*:

Current State: Wait for Response
Event: A data message frame is received but the S-bit is not toggled from the previous received data frame
Action: Send a positive acknowledgement but do not buffer the data packet. Acknowledgement frame format is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.3.2.8 *Wait for Data State Back to Wait for Data State (S-bit Toggled)*:

Current State: Wait for Response
Event: A data message frame is received and the S-bit is toggled from the previous received data frame
Action: Send a positive acknowledgement and buffer the data packet. Acknowledgement frame format is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.3.2.9 *Wait for Data State to Ready State*:

Current State: Wait for Data
Event: Private link address received; however, data was not successfully transferred.
Action: Layer 2 will generate a DL_SEND_BST_RESPOND.confirm to Layer 7 indicating that an activation was attempted, but the requested data was not received.
Next State: Ready

7.3.2.10 *Wait for Data State to Ready State*:

Current State: Wait for Data
Event: Uplink data transfer complete.
Action: Layer 2 will generate a DL_SEND_BST_RESPOND.confirm to Layer 7 indicating that a session has been established and conveying data from the OBE in response to the BST.
Next State: Ready

7.3.2.11 *Wait for Activation State to Wait for Response State*:

Current State: Wait for Activation
Event: A valid activation was received during activation windows allocated by the frame control frame. In addition, the R-bit of the Activation Frame's MAC field was set to 1 indicating that the private link address is active and thus the OBE is reactivating. See Fig. 24 and 7.5.1.11.
Action: Layer 2 will allocate media to the private link address contained within the activation. In the asynchronous mode, Layer 2 sends a data message frame that allocates media to the private link address as specified in 5.4.3. The L and A bit of the MAC field shall be set to 1 (AO_{16}).
In the synchronous mode, Layer 2 sends a frame control frame allocating a MDS to the private link address in the next TDMA frame by placing the link address in the SAT as specified in 5.2.3.
Next State: Wait for Data

7.3.2.12 *Wait for Response State Back to Wait for Response*

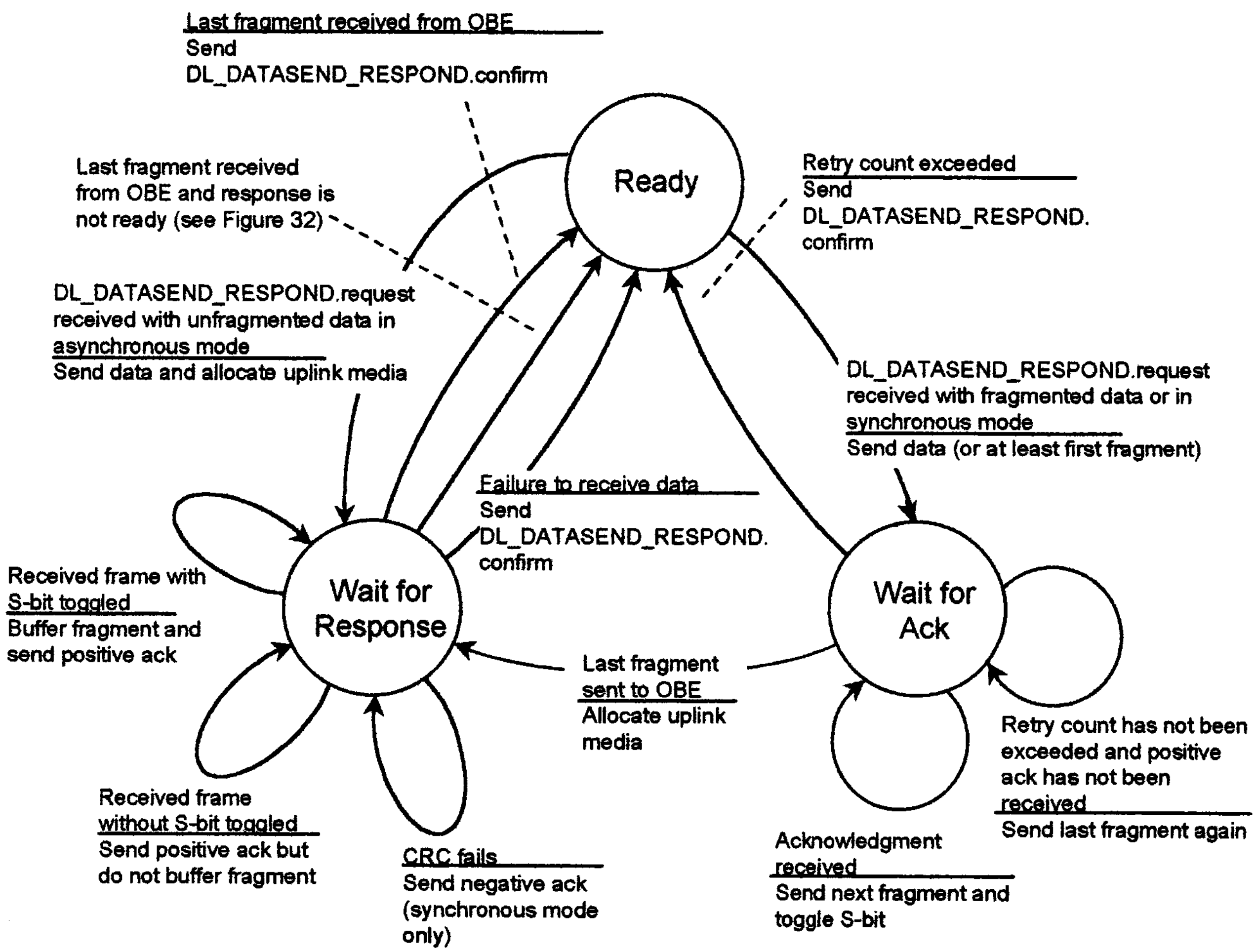

FIG. 24 RSE Data Transfer State Diagram

State (CRC Fails):

Current State: Wait for Response
Event: A frame is received but the CRC fails (in synchronous mode or if APDU is fragmented). Note that a retry count could be used to limit the number of consecutive failed transmission attempts. The threshold for the count is not defined in this document.
Action: Send a negative acknowledgement as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous) and allocate media for re-transmission as in 7.2.3.5.
Next State: Wait for Response

7.3.2.13 *Wait for Response State Back to Wait for Response State (S-bit Untoggled)*:

Current State: Wait for Response
Event: A data message frame is received but the S-bit is not toggled from the previous received data frame
Action: Send a positive acknowledgement but do not buffer the data packet. Acknowledgement frame format is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.3.2.14 *Wait for Response State Back to Wait for Response State (S-bit Toggled)*:

Current State: Wait for Response
Event: A data message frame is received and the S-bit is toggled from the previous received data frame
Action: Send a positive acknowledgement and buffer the data packet. Acknowledgement frame format is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.3.2.15 *Wait for Response State to Ready State*:

Current State: Wait for Data
Event: Uplink data transfer complete.
Action: Layer 2 will generate a DL_DATASEND_RESPOND.confirm to Layer 7 indicating that data was received from an OBE (private link address) that reactivated, thus completing the response to a previous DL_DATASEND_RESPOND.request. See Fig. 25 and 7.5.1.11.
Next State: Ready

7.3.3 *OBE Initialization Process*:

7.3.3.1 The state diagram for OBE initialization is depicted in Fig. 26. The OBE enters the Ready State when it completes the Layer 1 wake-up process or receives a DL_DATASEND-_RESPOND.response indicating that data is ready from a previous DL_DATASEND_RESPOND.indication and the OBE should reactivate.

7.3.3.2 Note that if there is a loss of RF signal, the OBE (in any state) will either return to the Ready State or enter directly

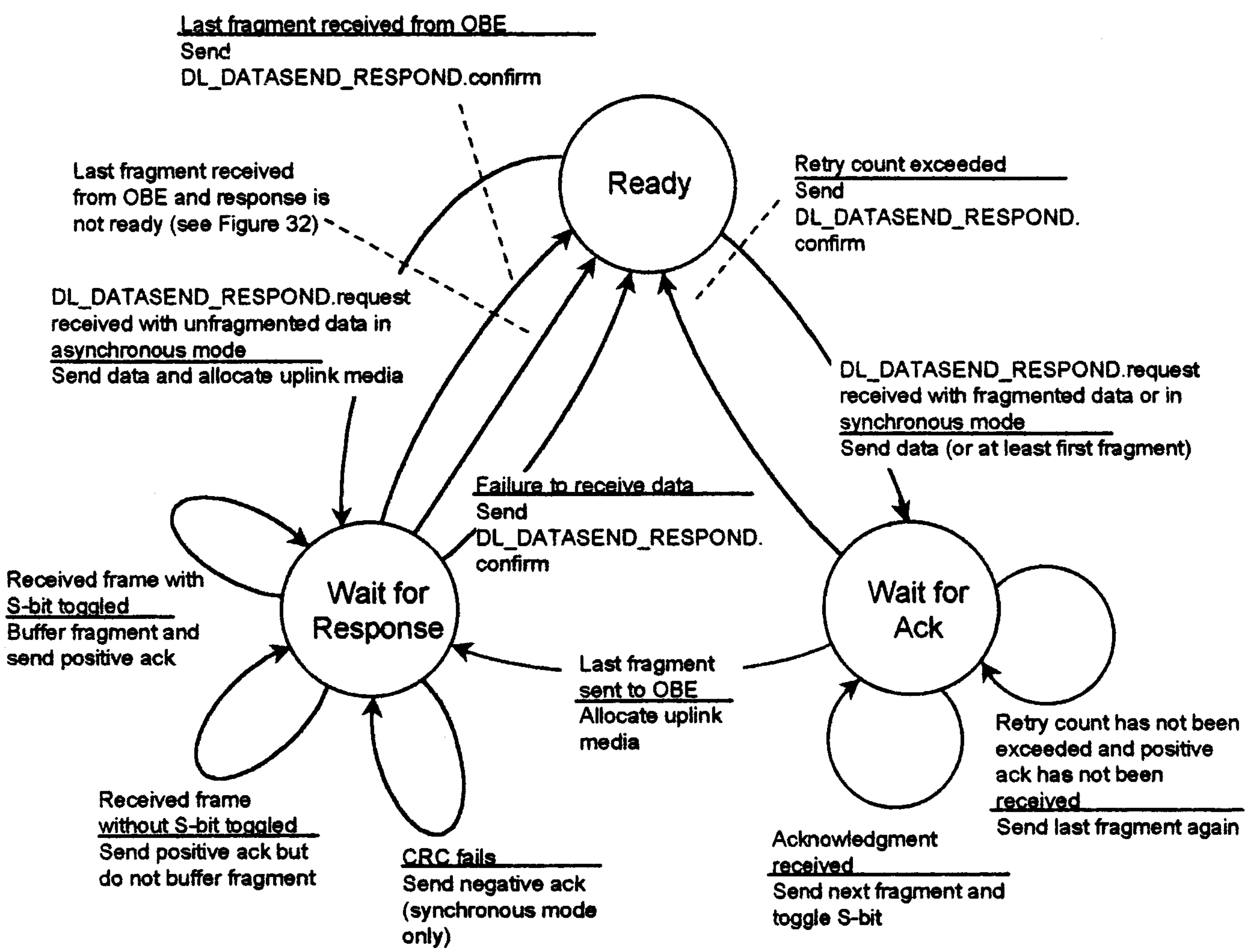

FIG. 25 RSE Data Transfer State Diagram

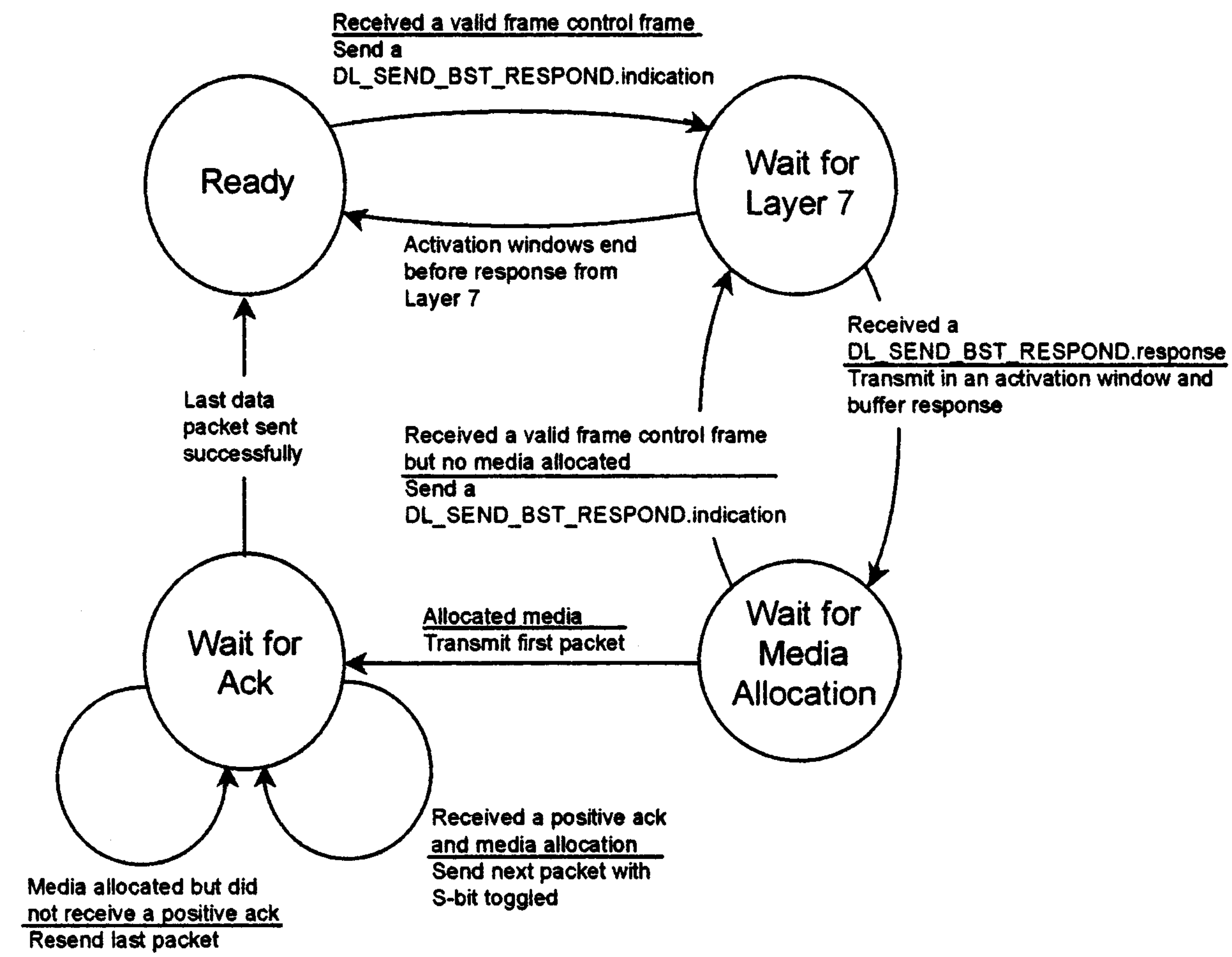

FIG. 26 OBE Initialization State Diagram

into sleep mode. In addition, the OBE Layer 2 may provide an indication to Layer 7.

7.3.3.3 *Ready State to Wait for Layer 7 State*:

Current State:	Ready
Event:	Received a valid frame control frame from Layer 1. Note that a frame control frame can be distinguished from other frames since it has a global address, a MAC field value of AO_{16} and a LLC field of 03_{16}.
Action:	Extract the FSI and SAT fields to prepare for activation Pass the link address and data to the OBE Layer 7 in a DL_SEND_BST_RESPOND.indication
Next State:	Wait for Layer 7

7.3.3.4 *Wait for Layer 7 State to Ready State (Time Out)*:

Current State:	Wait for Layer 7
Event:	Activation windows end before OBE Layer 7 sends a DL_SEND_BST_RESPOND.response to Layer 2
Action:	
Next State:	Ready

7.3.3.5 *Wait for Layer 7 State to Wait for Media Allocation State*:

Current State:	Wait for Layer 7
Event:	OBE Layer 7 sends a DL_SEND_BST_RESPOND.response to Layer 2
Action:	Buffer the data, create an activation frame and pass the activation frame to Layer 1. The activation frame shall be formatted as specified by 5.4.1.3 and 5.4.2. The D-bit in the MAC field of the activation frame shall be set to 1 (40_{16}). In addition, if the OBE is reactivating, set the R-bit in the MAC field to 1.
Next State:	Ready

7.3.3.6 *Wait for Media Allocation State to Wait for Layer 7 State*:

Current State:	Wait for Media Allocation
Event:	Received a valid frame control frame but no media was allocated
Action:	Send a DL_SEND_BST_RESPOND.indication to Layer 7 indicating error status
Next State:	Wait for Layer 7

7.3.3.7 *Wait for Media Allocation State to Wait for Ack State*:

Current State:	Wait for Media Allocation
Event:	OBE Layer 1 passes a frame to Layer 2 that allocates media for an OBE transmission. This frame could be a non-frame control frame with the private link address (in asynchronous mode only) or a frame control frame with the private link address in the SAT.
Action:	Transmit data in allocated media. In synchronous mode, create a slot data message frame as specified in 5.2.5 and pass to Layer 1. The control fields shall be set as follows: 1. Set the LLC field to 03_{16} 2. Set the L and D-bit in the MAC field to 1 (CO_{16}-if not fragmented) or the L, D and F-bit in the MAC field to 1 ($C2_{16}$-if fragmented) In the asynchronous mode, create a data message frame as specified in 5.4.3 and pass to Layer 1. The control fields shall be set as follows: 1. Set the LLC field to 03_{16} 2. Set the L and D-bit in the MAC field to 1 (CO_{16}-if not fragmented) or the L, D and F-bit in the MAC field to 1 ($C2_{16}$-if fragmented)

Next State: Wait for Ack

7.3.3.8 *Wait for Ack State Back to Wait for Ack State (Positive Ack)*:

Current State: Wait for Ack
Event: Received a positive acknowledgement and allocated uplink media
Action: Send next packet by creating a slot data message or a data message frame as specified in 5.2.5 or 5.4.3 and passing the frame to Layer 1. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L and D-bits in the MAC field to 1 and toggle the S-bit.
Next State: Wait for Ack

7.3.3.9 *Wait for Ack State Back to Wait for Ack State (Negative Ack)*:

Current State: Wait for Ack
Event: Allocated uplink media but did not receive a positive acknowledgement
Action: Resend last packet by creating a slot data message or a data message frame as specified in 5.2.5 or 5.4.3 and passing the frame to Layer 1. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L and D-bits in the MAC field to 1.
Next State: Wait for Ack

7.3.3.10 *Wait for Ack State to Ready State*:

Current State: Wait for Ack
Event: Received a positive acknowledgement for the last packet
Action:
Next State: Ready

7.3.4 *Initialization with DL_SEND_BST_RESPOND_REPEAT*:

7.3.4.1 The initialization process using DL_SEND_BST_RESPOND_REPEAT is illustrated in Fig. 27. It is the same process as described in 7.3.2.2 and 7.3.3 during tag activation. The primary difference from the process using the DL_SEND_BST_RESPOND primitive is indicated in highlighted text in Fig. 27 and illustrated in Fig. 28.

7.3.4.2 While there is a one-to-one correspondence between transmission of a frame control frame by the RSE and a DL_SEND_BST_RESPOND (Fig. 28(*a*)), only one DL_SEND_BST_RESPOND_REPEAT is required to cause multiple frame control frames to be transmitted (Fig. 28(*b*)). In addition, a single DL_SEND_BST_RESPOND_REPEAT.request can result in multiple OBE responses and thus multiple DL_SEND_BST_RESPOND_REPEAT.confirms issued by Layer 2 to Layer 7.

7.3.4.3 There is no change in the OBE initialization state diagram as described in 7.3.3. However, there will be minor deviations from the state diagram for RSE initialization depicted in Fig. 23 in 7.3.2.2.

7.4 *Data Transfer - No Response*:

7.4.1 Data transfer with no response requested by the RSE can be used to broadcast data to all OBEs in an RSE's field of view or it can be used to transfer data or commands to a specific OBE once the OBE has established a link with the RSE. Both of these modes of transfer employ the DL_DATASEND_NORESPOND primitive. An overview of the process is provided in Fig. 29.

7.4.2 *RSE Data Transfer Process*—The state diagram for the RSE data transfer process is depicted in Fig. 30.

7.4.2.1 *Ready State Back to Ready State*:

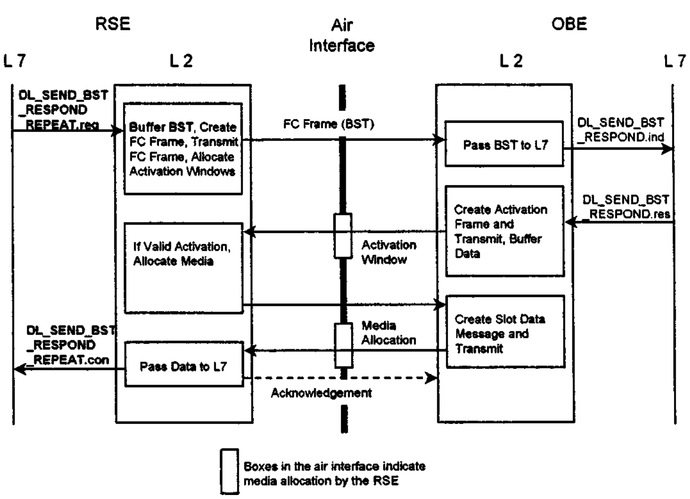

FIG. 27 Activation Process

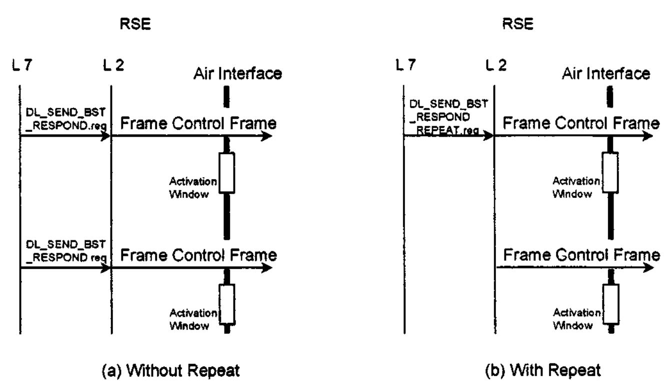

FIG. 28 Comparison of RSE Initialization Processes

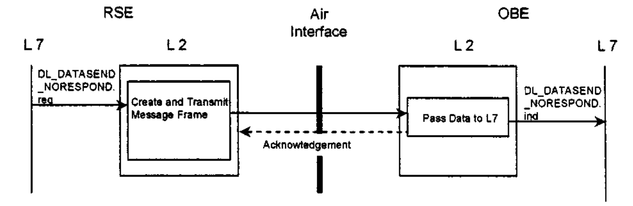

FIG. 29 Data Transfer Process Without a Response from the OBE

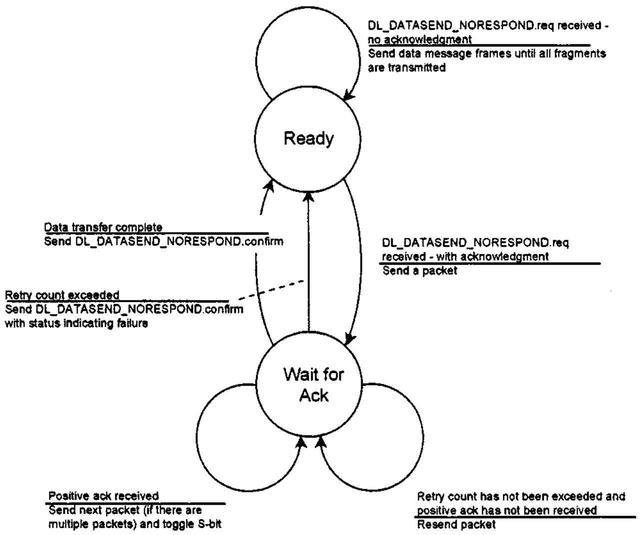

FIG. 30 RSE Data Transfer State Diagram

Current State: Ready
Event: RSE Layer 2 receives a DL_DATASEND_NORESPOND.request
Action: Layer 2 will generate a data message frame and pass the frame to Layer 1. The data message frame can be transmitted as described below:
In synchronous mode, select slot(s) for downlink transmission and indicate selection in SAT of the next Frame Control Frame (if there is an available slot). Then, create a slot data message frame as specified in 5.2.5 and pass to Layer 1 for transmission. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L and K-bit in the MAC field to 1 (81_{16}-if not fragmented) or the L, F and K-bit in the MAC field to 1 (83_{16}-if fragmented)
In the asynchronous mode, create a data message frame as specified in Section 5.4.3 and pass to Layer 1 for transmission. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L and K-bit in the MAC field to 1 (81_{16}-if not fragmented) or the L, F and K-bit in the MAC field to 1 (83_{16}-if fragmented)
If the APDU is fragmented, then this action will repeat until all fragments are transmitted (with the L and K-bits of the MAC field set to 1).
Next State: Ready

7.4.2.2 *Ready State to Wait for Ack State*:

Current State: Ready
Event: RSE Layer 2 receives a DL_DATASEND_NORESPOND.request
Action: Layer 2 will generate a data message frame and pass the frame to Layer 1. The data message frame can be transmitted as described below:
In synchronous mode, select slot(s) for downlink transmission and indicate selection in SAT of the next Frame Control Frame (if there is an available slot). Then, create a slot data message frame as specified in 5.2.5 and pass to Layer 1 for transmission. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L-bit in the MAC field to 1 (80_{16}-if not fragmented) or the L and F-bit in the MAC field to 1 (82_{16}-if fragmented)
In the asynchronous mode, create a data message frame as specified in 5.4.3 and pass to Layer 1 for transmission. Control fields shall be set as follows:
1. Set the LLC field to 03_{16}
2. Set the L-bit in the MAC field to 1 (80_{16}-if not fragmented) or the L and F-bit in the MAC field to 1 (82_{16}-if fragmented)
Next State: Wait for Acknowledgement

7.4.2.3 *Wait for Ack State Back to Wait for Ack State*:

Current State: Wait for Acknowledgement
Event: A positive acknowledgement was not received (either a negative acknowledgement was received or no acknowledgement was received within a certain time period) and the retry count did not exceed the threshold.
Action: Repeat action from 7.4.2.3.
Next State: Wait for Acknowledgement

7.4.2.4 *Wait for Ack State Back to Wait for Ack State*:

Current State: Wait for Acknowledgement
Event: A positive acknowledgement was received
Action: If another data packet should be transmitted, then repeat action from 7.4.2.2 except the modification to the MAC field bits indicated as follows: (1) L-bit set to 1, (2) toggle the value of the S-bit. Otherwise, no action.
Next State: Wait for Acknowledgement

7.4.2.5 *Wait for Ack State to Ready*:

Current State: Wait for Acknowledgement
Event: Data transfer is complete
Action: RSE Layer 2 issues a DL_DATASEND_NORESPOND.confirm indicating status of transfer
Next State: Ready

7.4.2.6 *Wait for Ack State to Ready*:

Current State: Wait for Acknowledgement
Event: Retry count threshold exceeded
Action: RSE Layer 2 issues a DL_DATASEND_NORESPOND.confirm indicating status of transfer
Next State: Ready

7.4.3 *OBE Data Transfer Process*—The OBE data transfer state diagram is depicted in Fig. 31. The OBE enters the ready state after completing initialization or if it receives a non-FC frame with a global link address.

7.4.3.1 *Ready State to Wait for Data State*:

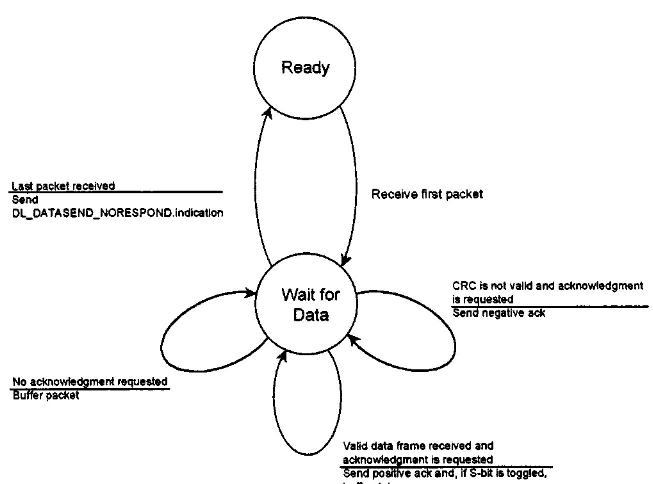

FIG. 31 OBE Data Transfer State Diagram

Current State:	Ready
Event:	OBE Layer 2 receives a frame from Layer 1 which is either a frame control frame allocating a MDS in synchronous mode or a downlink data message frame in asynchronous mode.
Action:	
Next State:	Wait for Data

7.4.3.2 *Wait for Data State Back to Wait for Data State (Negative Ack)*:

Current State:	Wait for Data
Event:	CRC fails for data message frame
Action:	Send a negative acknowledgement frame to the RSE. Format for frame is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous). In addition, MAC field shall be set as follows: (1) D and K-bit to 1 and (2) S-bit set to the same value as the S-bit in the data frame.
Next State:	Wait for Data

7.4.3.3 *Wait for Data State Back to Wait for Data State (Positive Ack)*:

Current State:	Wait for Data
Event:	OBE Layer 2 receives a valid data message frame
Action:	Send a positive acknowledgement frame to the RSE. Format for frame is specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous). In addition, MAC field shall be set as follows: (1) D-bit to 1, (2) K-bit to 0 and (3) setting the S-bit to the complement of the S-bit in the data frame. Buffer data packet (if S-bit is toggled)
Next State:	Wait for Data

7.4.3.4 *Wait for Data State Back to Wait for Data State (No Confirmation)*:

Current State:	Wait for Data
Event:	OBE Layer 2 receives data message frames
Action:	Buffer data packets until all fragments are received
Next State:	Wait for Data

7.4.3.5 *Wait for Data State to Ready State*:

Current State:	Wait for Data
Event:	OBE Layer 2 receives last data packet
Action:	Send a DL_DATASEND_NORESPOND.indication to OBE Layer 7
Next State:	Ready

7.4.4 *Data Transfer w/DL_DATASEND_NORESPOND_REPEAT*:

7.4.4.1 The data transfer process using DL_DATASEND_NORESPOND_REPEAT is the same process as described in 7.4.2 and 7.4.3 except the correlation between the primitive (.request) and the number of data message frames transmitted by the RSE Data Link Layer. The process using the two primitives is illustrated in Fig. 32. While there is a one-to-one correspondence between transmission of a frame control frame by the RSE and a DL_DATASEND_NORESPOND (Fig. 32(*a*)), only one DL_DATASEND_NORESPOND_REPEAT is required to cause multiple frame control frames to be transmitted (Fig. 32(*b*)).

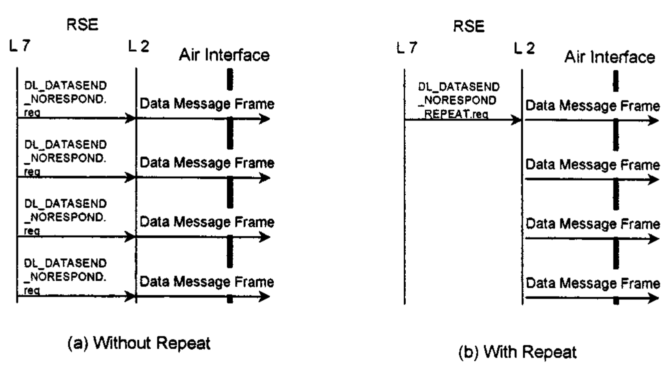

FIG. 32 Comparison of RSE Data Transfer Primitives

7.4.4.2 There is no change in the OBE data transfer state diagram as described in 7.4.3. However, there will be deviations from the state diagram for RSE data transfer depicted in Fig. 30 in 7.4.2.

7.5 *Data Transfer with Response*—Data transfer with response requested by the RSE can be used by the RSE to write data with confirmation, send commands with confirmation, read data, etc. This type of transfer employs the DL_DATASEND_RESPOND primitive. Examples of the flow can be found in 7.5.3.

7.5.1 *RSE Data Transfer Process*—The RSE data transfer state diagram is illustrated in Fig. 24.

7.5.1.1 *Ready State to Wait for Ack State*:

Current State:	Ready
Event:	RSE Layer 2 receives a DL_DATASEND_RESPOND.request and the data is fragmented or the link is operating in synchronous mode.
Action:	In synchronous mode, select slot(s) for downlink transmission and indicate selection in SAT of the next Frame Control Frame (if there is an available slot). Create a slot data message frame as specified in 5.2.5 and pass to Layer 1. Control fields shall be set as follows: 1. Set the LLC field to $E7_{16}$(no data requested) or $F7_{16}$(data requested) 2. Set the MAC field to 80_{16}(if not fragmented) or 82_{16}(if fragmented) In the asynchronous mode, create a data message frame as specified in 5.4.3 and pass to Layer 1. Control fields shall be set as follows: 1. Set the LLC field to $E7_{16}$(no data requested) or $F7_{16}$(data requested) 2. Set the MAC field to 81_{16}(if not fragmented) or 82_{16}(if fragmented)
Next State:	Wait for Data

7.5.1.2 *Wait for Ack State Back to Wait for Ack State (Retry Count)*:

Current State:	Wait for Acknowledgement
Event:	A positive acknowledgement was not received (either a negative acknowledgement was received or no acknowledgement was received within a certain time period) and the retry count did not exceed the threshold
Action:	Execute action from 7.5.1.1.
Next State:	Wait for Acknowledgement

7.5.1.3 *Wait for Ack State Back to Wait for Ack State (Ack Received)*:

Current State:	Wait for Acknowledgement
Event:	Received a positive acknowledgement.
Action:	If another data packet should be transmitted, then repeat action from 7.5.1.1 except the modification to the MAC field bits indicated as follows: (1) L-bit set to 1, (2) toggle the value of the S-bit.
Next State:	Wait for Acknowledgement

7.5.1.4 *Wait for Ack State to Ready State*:

Current State:	Wait for Acknowledgement
Event:	Retry count threshold exceeded
Action:	RSE Layer 2 issues a DL_DATASEND_NORESPOND.confirm indicating status of transfer
Next State:	Ready

7.5.1.5 *Wait for Ack State to Wait for Response State*:

Current State:	Wait for Acknowledgement
Event:	Last packet transmitted by RSE to the OBE
Action:	RSE Data Link Layer shall allocate uplink media for the response.

In synchronous mode, select slot for uplink transmission and indicate selection in SAT of the next Frame Control Frame (if there is an available slot)
In asynchronous mode, create a data message frame to allocate uplink media and pass to layer 1. The A-bit in the MAC field shall be set to 1 (20_{16})
Next State: Wait for Response

7.5.1.6 *Wait for Response Back to Wait for Response (CRC Fails)*:

Current State: Wait for Response
Event: A frame is received but the CRC fails (in synchronous mode)
Action: Send a negative acknowledgement. The acknowledgement frame shall be formatted as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.5.1.7 *Wait for Response Back to Wait for Response (S-bit Untoggled)*:

Current State: Wait for Response
Event: A data message frame is received but the S-bit is not toggled from the previous received data frame
Action: Send a positive acknowledgement but do not buffer the data packet. The acknowledgement frame shall be formatted as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous). All the bits of the MAC field of the acknowledgement frame shall be set to 0 with the exception of the S-bit which is the complement from the received frame
Next State: Wait for Response

7.5.1.8 *Wait for Response Back to Wait for Response (S-bit Toggled)*:

Current State: Wait for Response
Event: A data message frame is received and the S-bit is toggled from the previous received data frame
Action: Send a positive acknowledgement and buffer the data packet. Format for acknowledgement frame is defined in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Response

7.5.1.9 *Wait for Response to Ready (Last Packet)*:

Current State: Wait for Response
Event: Last packet transmitted by the OBE is received
Action: Send a DL_DATASEND_RESPOND.confirm to RSE Layer 7 containing the buffered data packets
Next State: Ready

7.5.1.10 *Wait for Response to Ready (Failure)*:

Current State: Wait for Response
Event: Failure to receive a response during allocated uplink media
Action: Send a DL_DATASEND_RESPOND.confirm to RSE Layer 7 indicating status
Next State: Ready

7.5.1.11 *Wait for Response to Ready (Response Not Ready)*:

Current State: Wait for Response
Event: OBE application layer indicates that response is not ready
Action:
Next State: Ready

7.5.1.12 *Ready State to Wait for Response State*:

Current State: Ready
Event: OBE Layer 2 receives a DL_DATASEND_RESPOND.request, the data is not fragmented and the tag is operating in asynchronous mode.
Action: Create a data message frame as specified in 5.4.3 and pass to Layer 1. Control fields shall be set as follows:
1. Set the LLC field to $E7_{16}$(no data requested) or $F7_{16}$(data requested)
2. Set the MAC field to 80_{16}

Once the data frame is transmitted, allocate uplink media for a response
Next State: Wait for Response

7.5.2 *OBE Data Transfer Process*—The OBE data transfer state diagram is illustrated in Fig. 33.

7.5.2.1 *Ready State to Wait for Data State*:

Current State: Ready
Event: Downlink media allocated. In the synchronous mode, this allocation will occur through the Frame Control Frame. In the asynchronous mode, this allocation will occur by the transmission of a frame with the OBE's private link address.
Action:
Next State: Wait for Data

7.5.2.2 *Wait for Data State Back to Wait for Data State (CRC Failure)*:

Current State: Wait for Data
Event: Received a data frame but the CRC failed
Action: Send a negative acknowledgement. The acknowledgement frame shall be formatted as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Data

7.5.2.3 *Wait for Data State Back to Wait for Data State (Valid Data)*:

Current State: Wait for Data
Event: Received a valid data frame
Action: Send a positive acknowledgement and buffer the data packet (if the S-bit was toggled. Otherwise, do not buffer the data packet). The acknowledgement frame shall be formatted as specified in 5.2.6 (synchronous) or 5.4.3 (asynchronous).
Next State: Wait for Data

7.5.2.4 *Wait for Data State to Wait for Layer 7 State*:

Current State: Wait for Data
Event: Last data packet transmitted by the RSE is received by the OBE
Action: Send buffered data packet to Layer 7 in a DL_DATASEND-_RESPOND.indication
Next State: Wait for Layer 7

7.5.2.5 *Wait for Layer 7 State to Wait for Ack State (Have Response)*:

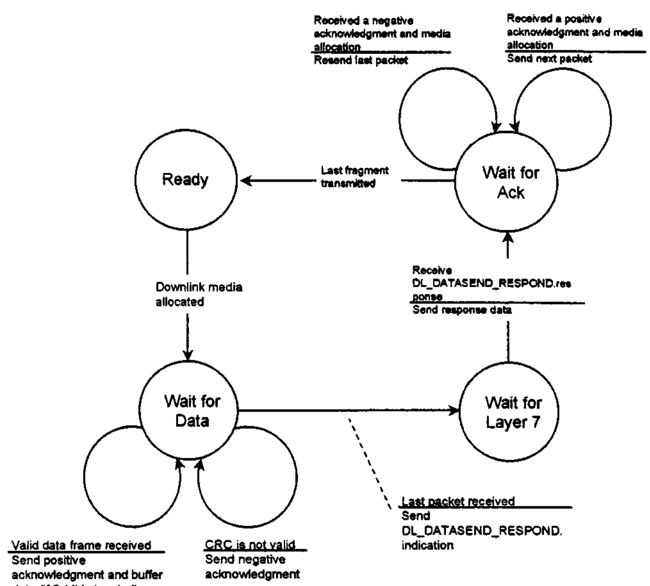

FIG. 33 OBE Data Transfer State Diagram

Current State: Wait for Layer 7
Event: Receive a DL_DATASEND_RESPOND.response from Layer 7 (or already have a response from Layer 7)
Action: Transmit response data packet in allocated uplink media. In the synchronous mode, the data packet shall be sent in a slot data message frame as specified in 5.2.5. The control fields shall be set as follows:
1. Set the LLC field to $E4_{16}$
2. Set the MAC field to $C2_{16}$(if fragmented) and C0 (if not fragmented)

In the asynchronous mode, the data packet shall be sent in a data message frame as specified in 5.4.3. The control fields shall be set as follows:
1. Set the LLC field to $E4_{16}$
2. Set the MAC field to $C2_{16}$(if fragmented) and C1 (if not fragmented)

Next State: Wait for Ack

7.5.2.6 *Wait for Ack State to Wait for Ack State (Retry Count)*:

Current State: Wait for ack
Event: A positive acknowledgement was not received (either a negative acknowledgement was received or no acknowledgement was received within a certain time period) and the retry count did not exceed the threshold.
Action: Transmit last packet again (no change to the frame format or the control fields)
Next State: Wait for Ack

7.5.2.7 *Wait for Ack State to Wait for Ack State (Positive Ack)*:

Current State: Wait for Ack
Event: A positive acknowledgement was received
Action: Transmit response data packet in allocated uplink media. In the synchronous mode, the data packet shall be sent in a slot data message frame as specified in 5.2.5. In the asynchronous mode, the data packet shall be sent in a data message frame as specified in 5.4.3. In either mode, the control fields shall be set as follows:
1. Set the LLC field to $E4_{16}$
2. Set the L, D, and C/R-bits of the MAC field to 1 and toggle the S-bit.

Next State: Wait for Ack

7.5.2.8 *Wait for Ack State to Ready State*:

Current State: Wait for Ack
Event: Last packet transmitted
Action:
Next State: Ready

7.5.3 *Data Transfer w/DL_DATASEND_RESPOND_REPEAT*:

7.5.3.1 The data transfer process using DL_DATASEND-_RESPOND_REPEAT is the same process as described in 7.5.1 and 7.5.2 except the correlation between the primitive (.request) and the number of data message frames transmitted by the RSE Data Link Layer. While there is a one-to-one correspondence between transmission of a frame control frame by the RSE and a DL_DATASEND_RESPOND, only one DL_DATASEND_RESPOND_REPEAT is required to cause multiple frame control frames to be transmitted.

7.5.3.2 There is no change in the OBE data transfer state diagram as described in 7.5.2. However, there will be deviations from the state diagram for RSE data transfer depicted in Fig. 24 in 7.5.1.

7.5.4 *Sample Process Flow Diagrams*—Figs. 34 and 35 contain sample process flow diagrams for two situations in which fragmented data must be sent either over the uplink or the downlink using data transfer with a response.

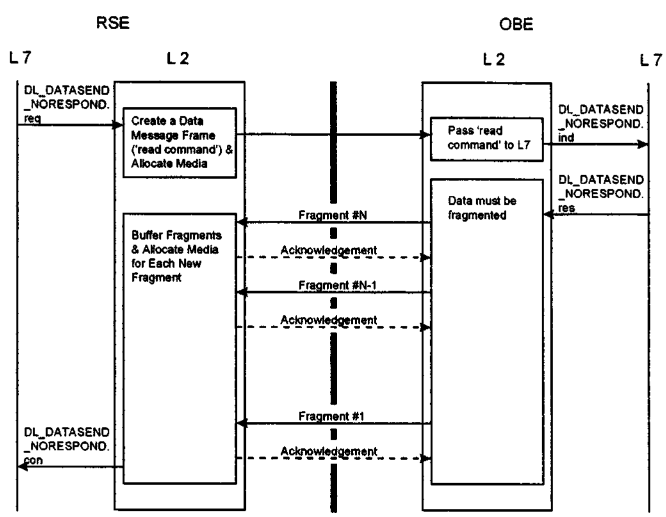

FIG. 34 Example of Data Transfer With a Fragmented Uplink Data Message

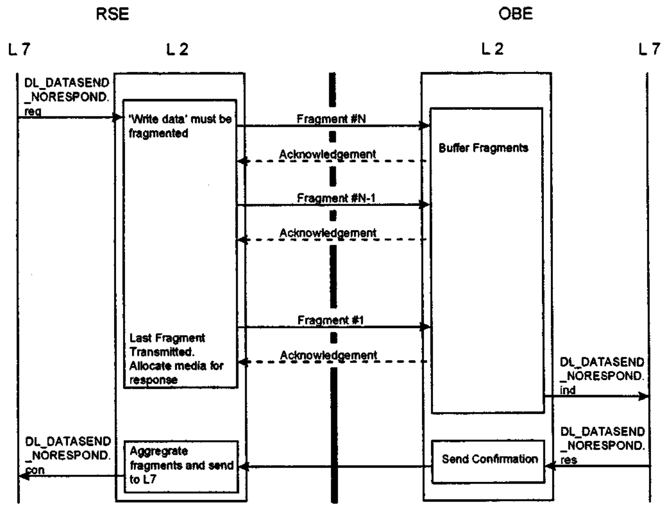

FIG. 35 Example of Data Transfer With a Fragmented Downlink Data Message

APPENDIXES

(Nonmandatory Information)

X1. INTEROPERABILITY WITH EXISTING EQUIPMENT

X1.1 This provisional specification is concerned with wireless communications between a system of readers and tags. Prior to nationwide conformance to this provisional specification, a number of manufacturers, including Amtech, Hughes Transportation Management Systems, Mark IV Industries, and Texas Instruments, have constructed and deployed equipment performing similar functions utilizing differing protocols. A technique is defined herein which will allow those differing pieces of equipment to non-destructively co-exist and operate.

X1.2 Due to the fact that the existing equipment is in general designed such that the reader initiates the communication session, control of the data link will reside within the reader(s).

X1.3 There is not imposed any requirement that any transponder respond to multiple protocols, although the use of such transponders within the system shall not be prohibited.

X1.4 The first level of all communication sessions, initiated by the reader, is called a query. A query is an attempt made by the reader in which the reader tries to determine if a tag with a compatible protocol is within its communication range. Each query shall consist of an interrogation followed by a period sufficient for any targeted transponder to respond.

X1.5 At any site or location at which it is desired to read transponders of particular manufacturers, the reader(s) or system of readers must be capable of performing queries for each of the differing protocols supported by the differing transponders which are desired to be read.

X1.6 Queries for non-interfering technologies may be executed simultaneously by capable reader equipment, but, queries issued to interfering technologies shall be executed in a sequence of consecutive queries called a scan cycle.

X1.7 A Scan cycle may be composed of a single type of query repeated continuously, or may be composed of a number of different types of queries which are each searching for a transponder responding to a different type of protocol. The composition of a scan cycle is dictated by the protocol, or protocols, necessary to fulfill the requirements of a particular application.

X1.8 *Illustrative Example*—Assume that Query 1 (Q1) is the continuous RF signal defined Manufacturer A, Query 2 (Q2) is the identification polling message defined by Manufacturer B, and Query 3 (Q3) is the Polling Message defined by manufacturer C. An appropriate scan cycle would be:

...Q1-Q2-Q3-Q1-Q2-Q3-Q1-Q2-Q3...

X1.9 Several protocol families are capable of being used within the scan cycle which will provide system integrators a tool kit of well documented, non-proprietary protocols. These protocol families are each documented by The manufacturers supplying the equipment.

X1.10 As a prerequisite to a protocol being used in such fashion within any installed system, it must be known that the protocol contains elements sufficient for use as a query.

X1.11 Simply using a protocol in a query-based system will not guarantee against the effect of incorrect application of technologies to intended purposes. System integrators shall understand themselves, or through their consultants and subcontractors, the effects of utilizing technologies and their suitability to applications.

X2. COMMUNICATION PROFILES

X2.1 Table X2.1 describes the communications profile options that shall be included in the BST.

TABLE X2.1 Profile Options

Identification Number	02_{16}	03_{16}	04_{16}	05_{16}
U1- Respond with either an Active Carrier or Backscattered carrier and sub-carriers as requested. 0 - Active 1 - Backscatter	Active	Backscatter	Active	Backscatter
D8 - Down link Bit Rate is defined by installation (and due to negotiations): Bit rate coded in 3 bits: 000 reserved for future use 001 31.25 kbps 010 62.5 kbps 011 125 kbps 100 250 kbps 101 500 kbps 110 reserved for future use 111 reserved for future use	Bit rate = 500 kbps	Bit rate = 500 kbps	Bit rate = 500 kbps	Bit rate = 500 kbps
D10 - Wakeup operation 0 - Slow wake-up operation 1 - Fast wake-up operation	Fast wake-up operation	Fast wake-up operation	Slow wake-up operation	Slow wake-up operation
U1b - For Backscatter, both side bands can be used independently. There are four possibilities coded as follows: 00 Reserved for future use 01 Same data in both sidebands 10 Data only in upper sideband 11 Different data in sidebands		Same data on both side bands		Same data on both side bands
U2 - In band power (adjusted) Active options: - Defined by installation (and due to negotiations): Coded in 1 bit: 0 - 0 to 6 dBm 1 - ≤ 20 dBm (67 volts/meter) in 3 Mhz	0 to 6 dBm	The OBE antenna shall have a (45 to 100 cm^2) delta RF cross section and the OBE output shall not exceed - 15 dBm in 100 kHz.	0 to 6 dBm	The OBE antenna shall have a (45 to 100 cm^2) delta RF cross section and the OBE output shall not exceed - 15 dBm in 100 kHz.
U8 - Uplink Bit Rate is defined by installation (and due to negotiations): Bit rate coded in 3 bit: 000 reserved for future use 001 31.25 kbps 010 62.5 kbps 011 125 kbps 100 250 kbps 101 500 kbps 110 750 kbps 111 reserved for future use	Bit Rate = 500 kbps	Bit Rate = 500 kbps	Bit Rate = 500 kbps	Bit Rate = 500 kbps
U6c - The Backscatter Data Modulation Order is defined by installation and due to negotiations. Coded in 2 bits: 00 M = 2 01 M = 4 10 reserved for future use 11 reserved for future use		Data Modulation Order M=2		Data Modulation Order M=2

X3. DOCUMENT CHANGE CONTROL

Registration by ASTM	Version	Date	Change Description
	0.0	January 21, 1997	Adoption as a work item and current active draft standard for the DSRC Data Link Layer: Media Access and Logical Link Control.
	0.1	Feb 4, 1997	Addition of Appendix X2 issues list and modification of text to reference Appendix X2.
	1.0	April 28, 1997	Modification to media access control sublayer reflecting outcome of March meeting in Dallas and April meeting in Washington. Addition of CEN developed logical link control sublayer to provided basis for further standards development.
	1.1	May 2, 1997	Update Appendix X2 and a few minor modifications
	1.2	May 20, 1997	Update Appendix X2 and resulting changes to Section 4 and 5.
	1.3	July 22, 1997	Update Appendix X2 resulting changes to Section 4 and 5.
	2.0	Nov 5, 1997	Modification to media access control sublayer reflecting outcome of October meeting in Fullerton, CA and August meeting in Washington.
	2.1	Dec 4, 1997	Modification to media access control sublayer reflecting outcome of November meeting in Albuqurque, NM.
	2.2	Jan 4, 1998	Modification to media access control sublayer reflecting outcome of December meeting in San Diego, CA.
	3.0	Feb 6, 1998	Proposed resolution to a number of media access control sublayer issues
	3.1	March 9, 1998	Include more overview information, refine media access control discussion
	4.0	April 2, 1998	Major document reorganization
	4.1	May 14, 1998	Modifications to logical link control section
	4.2	June 25, 1998	Change Section 7 to reflect state diagram orientation
	4.3	July 31, 1998	Modification based on June Toronto meetings
	4.4	Sept 29, 1998	Modifications based on August meetings at ARINC
	4.5	Oct 29, 1998	Final modifications before ballot