MIL-STD 188-220B Class B (Types 1 and 2) Link Layer Estelle Specification

The Class B Estelle specification is preceded by several diagrams and tables. They are:

- Datalink Layer Interface - an abstract view of the datalink layer's interface with its upper (Network) layer, its lower layer (Physical), and a proposed peer representing an operator or management component. This diagram summarizes all service primitives that define the information flow between the datalink layer and its neighboring layers.

- Datalink Layer Class B Architecture - an abstract, yet more detailed view of the proposed internal structure of the datalink layer. This architecture is modeled after ISO 8802 Link Layer specification, in particular, in the definition of a Station Component containing two SAP services: one for Type 1 and one for Type 2.

- Class B Station Component: This Component contains a Type 1 SAP Component and a Type 2 SAP Component. It accepts interactions from the Network and Physical layers and properly demultiplexes them to the appropriate Type SAP Component. For example, depending on the quality of service requested by a DL_Unitdata.Request, the Station Component will forward the request either to the Type 1 SAP Component or the Type 2 SAP Component. Prior to June 1996, the Station Component operation was divided into 3 phases: *initialization* when a station tries to join a net; *active* during normal operation when communicating with other nodes; and *leave* when a station leaves the network, either gracefully or abruptly. After June 1996, the CNR WG decided to replace joining/leaving the net via link layer actions with Network Layer XNP messages; thus the Station Component was reduced to a single active phase. The active phase is enhanced to handle the demultiplexing. Each phase has an EFSM diagram and a transition table. Additionally, the Station Component has a set of *common* transitions; these are transitions that define global independent actions (i.e., actions that may occur either regardless of the current state or for a large subset of states). This set was significantly reduced with the removal of XID PDUs from the link layer[1]

- The Type 1 Service Box has three components. This structure is identical to Class A (Type 1 only) service. The components are Type 1 SAP Component - performs all functionality to process incoming and outgoing Type 1 packets; Busy Timers - timers that keep record of which other stations on the net are ready/not ready to receive Type 1 packets; and Ack Timer - a timer needed for coupled acknowledgments. (A fourth component: NETCON was removed to the Network Layer when XID was replaced with XNP messages.)

- Type 1 SAP Component EFSM and State Transition Table: The Type 1 SAP Component has primary responsibility for processing DL_PDUs receiving type 1 service either with or without coupled ack, i.e., managing destination lists, starting and stopping timers for PDUs requiring retransmission, monitoring which destinations are ready to receive and which are not, etc.

- Busy Timer; Ack Timer EFSMs and State Transition Tables - these diagrams and tables summarize the behaviors of timers needed to manage acknowledgments.

- The Type 2 Service Box has several components. They are: Type 2 SAP Component; RR/RNR Busy Timers; P-bit Busy Timer; Ack Timer; and a Reject Timer

- Type 2 SAP Component EFSM and State Transition Table: In the spirit of 8802, this Component is further divided into a set of Type 2 Connection Components, one for each destination, and four Type 2 Timers associated with each Connection Component. Its main purposes are:

    - Forward messages between Station Component and Connection Components.

[1] To avoid possible confusion from renaming/renumbering transitions following removal of XID handling, transitions kept their original names/numbers. The removal of XID handling thus results in some numbering gaps.

- Process the first transmission of multi-destination PDUs with the cooperation of the Connection Components.
- Process indications from Connection Components (indications to be processed within datalink layer only).
- Initiate connect_requests, disconnect_requests and reset_requests.

- Type 2 Timers EFSMs and State Transition Table: There are four timer associated with each Connection Component: an Ack Timer, a Busy Timer, a Reject Timer, and a P-bit Timer. For example, the Busy Timer controls which other stations on the net are ready to receive Type 2 packets. These timers are relatively simple differing only on whether they restart their timer countdown if a *start timer* signal arrives at a time when the timer is already running.

- Type 2 Connection Component EFSMs and State Transition Table: There is a unique Connection Component for each remote destination this station communicates with. Due to its complexity, special details about how the Connection Components operate are discussed below.

- Estelle Specification - following discussion of the Connection Component and its documentation can be found 69 double pages defining the architecture and behavior of Class B Link Layer service.

Special Notes on the Design of the Type 2 Connection Component

Because of Type 2's significant complexity, it is important for the reader to understand how its Estelle specification was derived.

MIL-STD 188-220B's Type 2 Connection Component was based on and therefore is similar to the ISO 8022 Type 2 Connection Component. Hence, the process in developing our Estelle specification was as follows.

1. We carefully studied 8802.

2. We identified where 188-220B differs from 8802.

3. We modified 8802's state tables and diagrams to account for 188-220B's differences.

4. We derived an Estelle specification based on the modified 8802 information. The documentation provided with our Estelle specification includes sections from 8802 that have been modified.

In particular, the following sections of the 8802 document are vital for understanding 188-220B and our Estelle specification and should be reviewed by the reader:

- 8802 5.3.2 Type 2 operation parameters (pp 44-45) -This section describes various parameters associated with the control field formats in Type 2 operation.

- 8802 5.4.2 Type 2 operation commands and responses (pp 50-54) -This section describes various Type 2 PDUs: I-format, S-format and U-format PDUs.

- 8802 7.9 Precise description of the Type 2 procedures (pp 79-108) -This section contains: an overview of the Type 2 Connection Component, a detailed English description of states, events, and actions (pp 79-86); a diagram of the EFSM of the Type 2 Connection Component (Figure 26 - Connection Component state diagram (p 87)); and an EFSM transition table (Table 4 - Connection Component state transitions (p 88-108)).

As a result of Step 1 above, we identified the following major differences between the two documents ISO International Standard 8802-2 (1994 edition) and MIL-STD 188-220B and the impact of these differences on our specification. Four major differences were identified.

1. Multi-destination PDU operation

   The Multi-destination PDU operation is not an available service in 8802. By adding a multi-destination DL_Unitdata.Request service, 188-220B introduces significant complexity in Type 2's protocol operation. In 188-220B, a DL_Unitdata.Request with multi-destinations should cause only one PDU to be sent to multiple destination addresses, with different sequence number(s) and other control information for each destination. The request is first taken care of by the Type 2 SAP Component. The complexity that arises is the fact that at the precise moment when a DL_Unitdata.Request arrives at the Type 2 SAP Component, a subset of Connection Components may be in disconnected mode, or may be busy, or may have a closed sending window. The multi-destination PDU cannot be sent to that subset. Therefore the Connection Components have to be contacted to decide which specific destinations can be included in the multi-PDU. The semantics of handling the retransmission of this multi-PDU becomes even more complicated. The 188-220B document is unclear on this point. As such, our specification uses the multi-PDU feature only in the first transmission. After the first transmission, the multi-PDU is conceptually split into multiple individual PDUs with each one's retransmissions, if any, handled by each individual Connection Component. This is reasonable since retransmissions to different destinations are likely to occur at different time instants as and when the individual timers expire, when connections are reestablished, when closed sending windows reopen, etc. Accordingly, the multi-PDU handling is specified as follows:

   Type 2 SAP Component: Upon receiving a DL_Unitdata.Request for multiple destinations, the SAP Component transmits an internal interaction to the Connection Components of every destination, one copy per destination. The SAP Component then builds an output buffer for collecting a yes/no response from every Connection Component. (Further DL_Unitdata.Requests are not processed until Connection Components respond.)

   For each destination, the SAP Component awaits a response. Only if the response is positive does the SAP Component fill the output buffer with the destination address. When all responses are received, the SAP Component constructs a multi-PDU for those Connection Components responding yes, and sends it to the Station Component for transmission.

   Type 2 Connection Component: Upon receiving a split MULTIDATA_REQUEST, the Connection Component determines if the PDU may be sent immediately. Does a connection exist? Is the destination free? Is the send window open? If all answers are yes, the Connection Component outputs a positive response to the Type 2 SAP Component with sequence number information and buffer the PDU for possible future retransmission. Otherwise, the Connection Component outputs a negative response to Type 2 SAP Component, buffer the PDU for transmission (once a negative response is sent, the Type 2 SAP Component will no longer handle the PDU for this destination), and opens a connection if needed.

2. RSET operation

   In 8802, when a PDU is received with invalid N(S), ``the LLC shall request a resetting procedure (by sending an FRMR response PDU)'' (8802 Section 7.7, p 77).
   In 188-220B, however, a RSET command PDU can be used for sequence number resetting.
   ``The RSET command may be sent by the station that detects an invalid N(R) to clear such a frame rejection condition in place of sending a FRMR frame.'' (188-220B 5.3.7.2.7, p 5-52)

   In 8802, ``Upon reception of an FRMR response PDU (even during an FRMR exception condition) the LLC shall initiate a resetting procedure by passing a DL-RESET indication primitive to the network layer'' (8802 7.6, p 77).
   In 188-220B, however, upon receiving the FRMR response PDU, the remote station may initiate a resetting procedure by sending a RSET command (188-220B 5.3.7.2.6, p 5-52)).
   Our interpretation is that if the reason for the FRMR PDU is an N(S) error, the RSET may be sent to reset the sequence number N(S).

   Accordingly, we added two new states to those defined in 8802 named RSET and RSET_EXPECTED.

   State RSET is entered when the local Connection Component has sent an RSET command PDU as the result of detecting an invalid N(R) or that the remote station has detected an invalid N(S) in a PDU and has sent an FRMR to this station.

State RSET_EXPECTED is entered when the local Connection Component has detected an invalid N(S) in a PDU and has sent an FRMR. It is expecting an RSET command PDU from the remote station.

3. SREJ operation
   In 8802, only Go-Back-N is available. This is implemented via the REJ PDU. 188-220B also has a SREJ (Selective Reject) PDU. A Connection Component may choose to use one or the other, but not both concurrently. A boolean function IS_SREJ_USED is used to distinguish whether or not a Connection Component is using SREJ in preference to REJ. The 8802 states REJECT and AWAIT_REJECT, and the REJ Timer are redefined to be used in both situations: whether Reject or Selective Reject is used. Upon receiving a SREJ PDU, a Connection Component will retransmit only the single requested PDU specified by the N(R) number in SREJ PDU (Selective Reject), as opposed to the action taken when REJ PDU (Go-Back-N) is received.

   Upon receiving a PDU with unexpected N(S), SREJs will be sent from V(R) up to N(S)-1 (even in the situation when the station is already in the reject condition.)

4. Network layer indications

   In 8802, many events cause indications to the network layer and actions are suspended waiting for responses from the network layer. In 188-220B, several similar decisions are made within the datalink layer. In our specification, the Connection Component still outputs indications. However, they are not sent to the network layer, but rather to the Type 2 SAP Component. Thus the datalink layer makes its own decisions, as is required by 188-220B, and the 8802 specification is retained with minimum modifications.

To accommodate these differences between 8802 and 188-220B, the semantics of certain 8802 states, events and actions had to be modified. Several new states, events, and action descriptions had to be added. These modifications and additions are now discussed. The actual tables and figures appear before the Estelle specification.

- Changes to the English description in 8802 Section 7.9 Precise description of the Type 2 procedures (pp79-86).
- Modification of 8802 transition EFSM (modified 8802 Figure 26, p 87) Changes are shown with two new states RSET and RSET_EXPECTED added.
- Modification of 8022 Table 4 containing Type 2 transitions (modified 21 pages) (pp88-108). Our work is based on the complex 21 page 8802 transition Table 4 which defines hundreds of transitions. To document these changes, we modified the original Table 4 and include the marked tables here. Some 8802 transitions are not needed in 188-220B and are crossed out. Some 8802 transitions need minor change in 188-220B and these changes are made on the original table. Some new transitions are added directly in the original 8802 Table 4 when space allows.
- Additional Modifications to 8802 Table 4 (new table ``Modification") When room in the original 8802 Table 4 for modified transitions was unavailable, the transitions were placed in a new table. In 8802, the reader is referred to ``See Modification pages."
- Transitions added to 8802 to handle Multi-destination I PDUs (new ``Multi" table). References to new transitions to handle multi-destination PDUs are made in the original 8802 Table 4 with the pointer ``See Multi table." The Multi-table follows the modified 8802 Table 4 and contains the transitions needed by a Connection Component to implement multi-destination PDUs.

- RSET and RSET_EXPECTED Transitions (new tables/diagrams). RSET is a new feature provided in 188-220B. Two new states are added for it: RSET and RSET_EXPECTED together with roughly 50 new transitions that are fired from the two states. These changes are summarized in EFSM diagrams and tables: ``Connection Component: RSET transitions" and ``Connection Component: RSET_EXPECTED transitions. "**In summary, the transition table for 188-220B's Type 2 Connection Component consists of: ``RSET and RSET_EXPECTED transitions" table, the marked 8802 Table 4, the ``Modification'' table, and the ``Multi'' table.**