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Request for Comments: 1434   D. Kushi
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                                                        March 1993

                 Data Link Switching: Switch-to-Switch Protocol

Status of this Memo

   This memo provides information for the Internet community. It does
   not specify an Internet standard. Distribution of this memo is
   unlimited.

Abstract

   This RFC describes IBM's support of Data Link Switching over TCP/IP.
   The RFC is being distributed to members of the Internet community in
   order to solicit their reactions to the proposals contained in it.
   While the issues discussed may not be directly relevant to the
   research problems of the Internet, they may be interesting to a
   number of researchers and implementors.

   Any questions or comments relative to the contents of this RFC should
   be sent to the following Internet address: dlsw@ralvma.vnet.ibm.com.

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1. Introduction

   Data Link Switching (DLS) is a forwarding mechanism for the IBM SNA
   and IBM NetBIOS protocols. It does not provide full routing, but
   instead provides switching at the Data Link layer and encapsulation
   in TCP/IP for transport over the Internet. This memo documents the
   Switch-to-Switch Protocol (SSP) that is used between IBM 6611 Network
   Processors.

   Today, the IBM 6611 supports SNA (PU 2 and PU 4) systems and NetBIOS
   systems attached to token-ring networks, as well as SNA (PU 2)
   systems attached to SDLC links. For the later case, the SDLC
   attached systems are provided with a LAN appearance within the IBM
   6611. For the LAN attached systems, the IBM 6611 appears as a
   source-routing bridge. Remote systems that are accessed through the
   IBM 6611 appear as systems attached to an adjacent ring. This ring
   is a virtual ring that is manifested within each IBM 6611.

2. Overview

   Data Link Switching was developed to provide support for SNA and
   NetBIOS in multi-protocol routers. Since SNA and NetBIOS are
   basically connection oriented protocols, the Data Link Control
   procedure that they use on the LAN is IEEE 802.2 Logical Link Control
   (LLC) Type 2. Data Link Switching also accommodates SNA protocols
   over WAN links via the SDLC protocol.

   IEEE 802.2 LLC Type 2 was designed with the assumption that the
   network transit delay would be small and predictable (i.e., a local
   LAN). Therefore the LLC elements of procedure use a fixed timer for
   detecting lost frames. When bridging is used over wide area lines
   (especially at lower speeds), the network delay is larger and it can
   vary greatly based upon congestion. When the delay exceeds the
   time-out value LLC attempts to retransmit. If the frame is not
   actually lost, only delayed, it is possible for the LLC Type 2
   procedures to become confused. And as a result, the link is
   eventually taken down.

   Given the use of LLC Type 2 services, Data Link Switching addresses
   the following bridging problems:

        DLC Time-outs
        DLC Acknowledgments over the WAN
        Flow and Congestion Control
        Broadcast Control of Search Packets
        Source-Route Bridging Hop Count Limits

   NetBIOS also makes extensive use of datagram services that use LLC

Type 1. In this case, Data Link Switching addresses the last two
problems in the above list.

The principal difference between Data Link Switching and bridging is
that DLS terminates the Data Link Control whereas bridging does not.
The following figure illustrates this difference based upon two end
systems operating with LLC Type 2 services.

```
 Bridging
 --------              Bridge          Bridge
 +------+              +----+          +----+            +------+
 | End  | +---------+ |    +-----/    |    | +---------+ | End  |
 |System+-+  LAN    +-+    |   /------+    +-+   LAN    +-+System|
 |      | +---------+ |    | TCP/IP  |    | +---------+ |      |
 +------+              +----+          +----+            +------+
Info------------------------------------------------------->
    <------------------------------------------------------RR


 Data Link Switching
 -------------------
 +------+              +----+          +----+            +------+
 | End  | +---------+ |    +-----/    |    | +---------+ | End  |
 |System+-+  LAN    +-+DLS |   /------+ DLS+-+   LAN    +-+System|
 |      | +---------+ |    | TCP/IP  |    | +---------+ |      |
 +------+              +----+          +----+            +------+
Info------------------>  ------------> Info
    <------------------RR                 --------------->
                                         <---------------RR
```
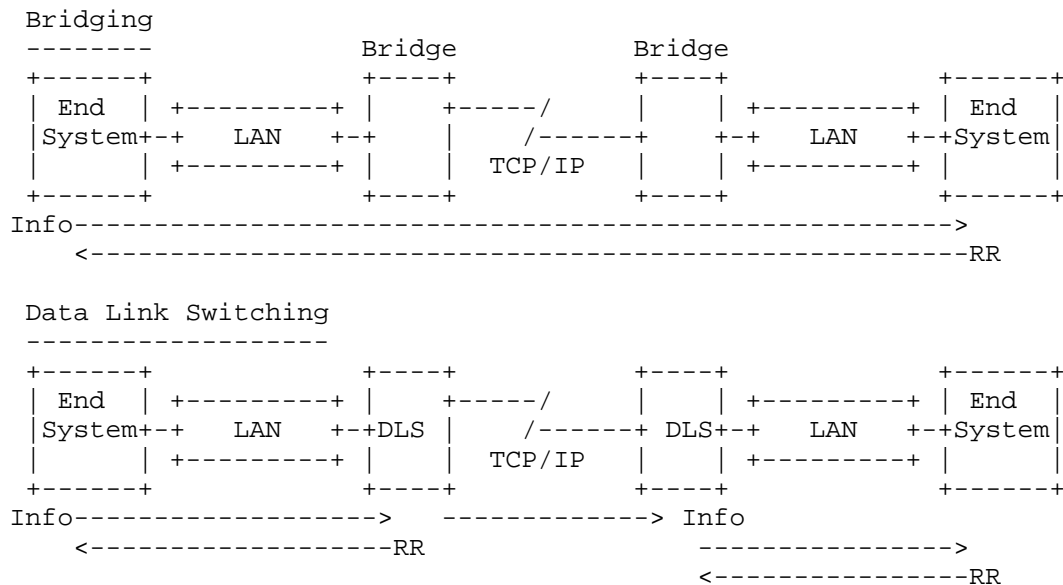
         Figure 1. Data Link Switching Contrasted to Bridging

In traditional bridging, the Data Link Control is end-to-end. Data
Link Switching terminates the LLC Type 2 connection at the switch.
This means that the LLC Type 2 connections do not cross the wide area
network. The DLS multiplexes LLC connections onto a TCP connection
to another DLS. Therefore, the LLC connections at each end are
totally independent of each other. It is the responsibility of the
Data Link Switch to deliver frames that it has received from a LLC
connection to the other end. TCP is used between the Data Link
Switches to guarantee delivery of frames.

As a result of this design, LLC time-outs are limited to the local
LAN (i.e., they do not traverse the wide area). Also, the LLC Type 2
acknowledgments (RR's) do not traverse the WAN, thereby reducing
traffic across the wide area links. For SDLC links, polling and poll
response occurs locally, not over the WAN. Broadcast of search
frames is controlled by the Data Link Switches once the location of a
target system is discovered. Finally, the switches can now apply

back pressure to the end systems to provide flow and congestion
control.

Data Link Switching uses LAN addressing to set up connections between
SNA systems. SDLC attached devices are defined with MAC addresses to
enable them to communicate with LAN attached devices. For NetBIOS
systems, Data Link Switching uses the NetBIOS name to forward
datagrams and to set up connections for NetBIOS sessions. For
circuit establishment, SNA systems send TEST (or in some cases, XID)
frames to the null (x'00') SAP. NetBIOS systems have an address
resolution procedure, based upon the Name Query and Name Recognized
frames, that is used to establish an end-to-end circuit.

Since Data Link Switching may be implemented in multi-protocol
routers, there may be situations where both bridging and switching
are enabled. SNA frames can be identified by their link SAP.
Typical SAP values for SNA are x'04', x'08', and x'0C'. NetBIOS
always uses a link SAP value of x'F0'.

3. Transport Connection

Data Link Switches can be in used in pairs or by themselves. A
Single DLS internally switches one data link to another without using
TCP (DLC(1) to DLC(2) in the figure below). A paired DLS multiplexes
data links over a reliable transport using a Switch-to-Switch
Protocol (SSP). This RFC will document the frame formats and
protocols for this multiplexing between Data Link Switches. The
initial implementation of SSP uses TCP as the reliable transport
between Data Link Switches. However, other transport connections
such as OSI TP4 could be used.

```
    +-------------------------------------------------+Switch-to-Switch
    |                  DLC Interfaces                 | Protocol (SSP)
    |+-----------+    DLC Request    +-----------+   |
    ||    Data   |<--------------- |           |   |Send SSP Frame
    ||    Link   | DLC Indication  |           |   ||-------------->
    || Control 1 |---------------->|           |   |
    |+-----------+                 | Data Link |   |
    |+-----------+   DLC Request   |  Switch   |   |
    ||    Data   |<--------------- |           |   |Rec. SSP Frame
    ||    Link   | DLC Indication  |           |   ||<-------------
    || Control 2 | --------------->|           |   |
    |+-----------+                 +-----------+   |
    |             Multi-Protocol Router             |
    +-------------------------------------------------+
```
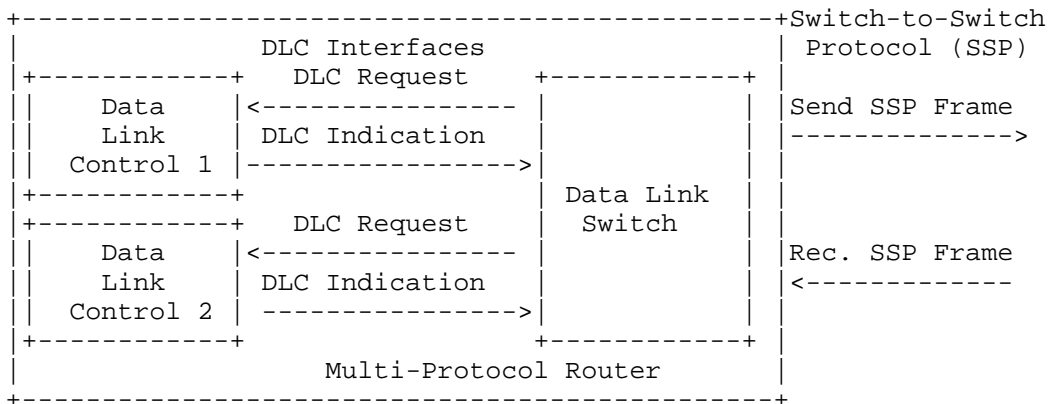
Figure 2. DLS System Diagram

Before Data Link Switching can occur between two routers, they must
establish a TCP connection between them. Each DLS will maintain a
list of DLS capable routers and their status (active/inactive). Once
this connection is established, the DLS will employ SSP to establish
end-to-end circuits over the transport connection. Within the
transport connection is a specific set of DLS message units. The
message formats and types for these PDUs are documented in the
following sections.

The default parameters associated with the TCP connections between
Data Link Switches are as follows:

```
        Socket Family     AF_INET        (Internet protocols)
        Socket Type       SOCK_STREAM    (stream socket)
        Read Port Number  2065
        Write Port Number 2067
```

Two or more Data Link Switches may be attached to the same LAN,
consisting of a number of token-ring segments interconnected by
source-routing bridges. In this case, a TCP connection is not
defined between bridges attached to the same LAN. This will allow
using systems to select one of the possible Data Link Switches in a
similar manner to the selection of a bridge path through a source-
routed bridged network. The virtual ring segment in each Data Link
Switch attached to a common LAN must be configured with the same ring
number. This will prevent LAN frames sent by one Data Link Switch
from being propagated through the other Data Link Switches.

3.1. SSP Frame Formats

The following diagrams show the two message headers for traffic
between Data Link Switches. The control message header is used for
all messages except information messages. The information message
header is 16 bytes long, and the control message header is 72 bytes
long. The first sixteen bytes of the control message header are
identical to the information message header.

```
  CONTROL MESSAGES (72 Bytes)
+-----------------------------------------------------------------+
| Version Number                   Reserved Field                |
| Message Length           ---->             .                   |
| Remote Data Link Correlator  ---->         .                   |
|             .                              .                   |
| Remote DLC Port ID         ---->           .                   |
|             .                              .                   |
| Reserved Field             ---->           .                   |
| Message Type                    Reserved Field                 |
| Protocol ID                     Header Number                  |
| Header Length              ---->           .                   |
| Reserved Field             ---->           .                   |
| Reserved Field                  Message Type                   |
| Target MAC Address         ---->           .                   |
|             .                              .                   |
|             .                              .                   |
| Origin MAC Address         ---->           .                   |
|             .                              .                   |
|             .                              .                   |
| Origin Link SAP                 Target Link SAP                |
| Frame Direction                 Reserved Field                 |
| Message Length             ---->           .                   |
| DLC Header Length          ---->           .                   |
| Origin DLC Port ID         ---->           .                   |
|             .                              .                   |
| Origin Data Link Correlator  ---->         .                   |
|             .                              .                   |
| Origin Transport ID        ---->           .                   |
|             .                              .                   |
| Target DLC Port ID         ---->           .                   |
|             .                              .                   |
| Target Data Link Correlator  ---->         .                   |
|             .                              .                   |
| Target Transport ID        ---->           .                   |
|             .                              .                   |
| Reserved Field             ---->           .                   |
|             .                              .                   |
+-----------------------------------------------------------------+
        (Even Byte)                     (Odd Byte)
```

INFORMATION MESSAGE (16 Bytes)
```
  +----------------------------------------------------------------+
  | Version                          Reserved Field                |
  | Message Length                 ---->             .             |
  | Remote Data Link Correlator    ---->             .             |
  |              .                                   .             |
  | Remote DLC Port ID             ---->             .             |
  |              .                                   .             |
  | Reserved Field                 ---->             .             |
  | Message Type                     Reserved Field                |
  +----------------------------------------------------------------+
          (Even Byte)                     (Odd Byte)
```

The Version Number is set to x'4B', indicating a numeric value of 75.

The Header Length is x'00 48', indicating a numeric value of 72
bytes.

The Header Number is x'01', indicating a value of one.

The Frame Direction field is set to x'01' for frames sent from the
origin DLS to the target DLS, and is set to x'02' for frames sent
from the target DLS to the origin DLS.

   Note: The Remote Data Link Correlator and Remote DLC Port ID are
   set equal to the Target Data Link Correlator and Target DLC Port
   ID if the Frame Direction field is set to x'01', and are set equal
   to the Origin Data Link Correlator and Origin DLC Port ID if the
   Direction Field is set to x'02'.

The Protocol ID field is set to x'42', indicating a numeric value of
66.

The Message Length field defines the number of bytes within the data
field following the header. Note that this value is specified in two
different fields of the message header.

The DLC Header Length is set to zero for SNA and is set to x'23' for
NetBIOS datagrams, indicating a length of 35 bytes. This includes
the Access Control (AC) field, the Frame Control (FC) field,
Destination MAC Address (DA), the Source MAC Address (SA), the
Routing Information (RI) field (padded to 18 bytes), the Destination
link SAP (DSAP), the Source link SAP (SSAP), and the LLC control
field (UI).

The values for the Message Type field are defined in a later section.
Note that this value is specified in two different fields of the
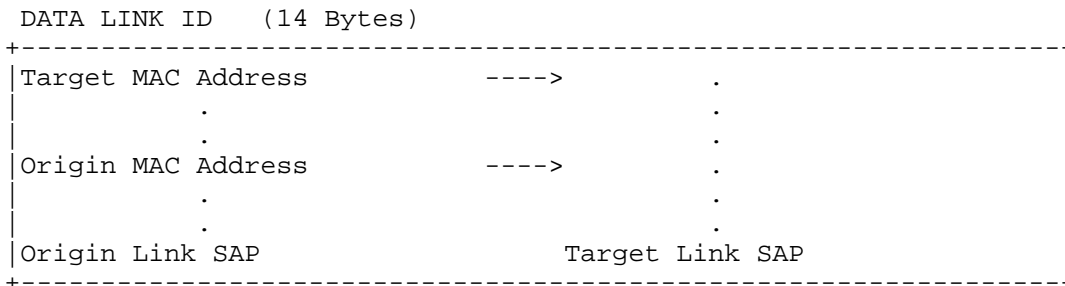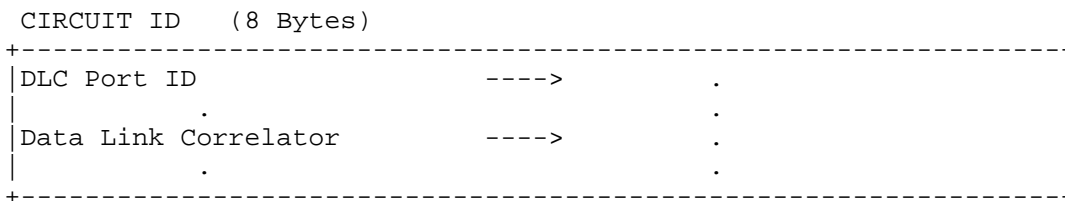message header.

Reserved fields are set to zero upon transmission and should be ignored upon receipt.

3.2. Address Parameters

A data link is defined as a logical association between the two end stations using Data Link Switching. It is identified by a Data Link ID (14 bytes) consisting of the pair of attachment addresses associated with each end system. Each attachment address is represented by the concatenation of the MAC address (6 bytes) and the LLC address (1 byte).

```
  DATA LINK ID   (14 Bytes)
  +---------------------------------------------------------------+
  |Target MAC Address            ---->          .                 |
  |          .                                  .                 |
  |          .                                  .                 |
  |Origin MAC Address            ---->          .                 |
  |          .                                  .                 |
  |          .                                  .                 |
  |Origin Link SAP                   Target Link SAP              |
  +---------------------------------------------------------------+
```

An end-to-end circuit is identified by a pair of Circuit ID's. A Circuit ID is a 64 bit number that identifies the DLC circuit within a single DLS. It consists of a DLC Port ID (4 bytes), and a Data Link Correlator (4 bytes). This value is unique in a single DLS and is assigned locally. The pair of Circuit ID's along with the identifiers of the Data Link Switches, uniquely identify a single end-to-end circuit. Each DLS must keep a table of these Circuit ID pairs, one for the local end of the circuit and the other for the remote end of the circuit. In order to identify which Data Link Switch originated the establishment of a circuit, the terms, origin DLS and target DLS, will be employed in this document.

```
  CIRCUIT ID   (8 Bytes)
  +---------------------------------------------------------------+
  |DLC Port ID                   ---->          .                 |
  |          .                                  .                 |
  |Data Link Correlator          ---->          .                 |
  |          .                                  .                 |
  +---------------------------------------------------------------+
```

The Origin Transport ID and the Target Transport ID fields in the message header are used to identify the individual TCP/IP port on a Data Link Switch. The values have only local significance. However, each Data Link Switch is required to reflect the values contained in these two fields, along with the associated values for DLC Port ID

and the Data Link Correlator, when returning a message to the other
Data Link Switch.

The following figure shows the use of the addressing parameters
during the establishment of an end-to-end connection. The CANUREACH,
ICANREACH, and REACH_ACK messages all carry the Data Link ID,
consisting of the MAC and Link SAP addresses associated with the two
end stations. Upon receipt of a CANUREACH message, the target DLS
starts a data link for each port, thereby obtaining a Data Link
Correlator. If the target station can be reached, an ICANREACH
message is returned to the origin DLS containing the Target Circuit
ID parameter. Upon receipt, the origin DLS starts a data link and
returns the Origin Circuit ID to the target DLS within the REACH_ACK
message. If the REACH_ACK message is not successfully received, the
target Data Link Switch can obtain the Origin Circuit ID from a
subsequent message (i.e., CONTACT, XIDFRAME, or DGRMFRAME).

```
   +------------+                                   +------------+
   |Disconnected|                                   |Disconnected|
   +------------+       CANUREACH (Data Link ID)    +------------+
        ------------------------------------------------->
           ICANREACH (Data Link ID, Target Circuit ID)
        <-------------------------------------------------
       REACH_ACK (Data Link ID, Origin Cir ID, Target Cir ID)
        ------------------------------------------------->
   +------------+                                   +------------+
   |Circuit Est.|                                   |Circuit Est.|
   +------------+                                   +------------+
       XIDFRAME (Data Link ID, Origin Cir ID, Target Cir ID)
        <------------------------------------------------->
      CONTACT (Data Link ID, Origin Cir ID, Target Cir ID)
        ------------------------------------------------->
     CONTACTED (Data Link ID, Origin Cir ID, Target Cir ID)
        <-------------------------------------------------
   +------------+                                   +------------+
   | Connected  |                                   | Connected  |
   +------------+                                   +------------+
        INFOFRAME (Remote Circuit ID = Target Circuit ID)
        ------------------------------------------------->
        INFOFRAME (Remote Circuit ID = Origin Circuit ID)
        <-------------------------------------------------
```

Figure 3. DLS Circuits and Connections

During the exchange of the XIDFRAME, CONTACT, and CONTACTED messages,
the pair of Circuit ID parameters is included in the message format
along with the DATA LINK ID parameter. Once the connection has been
established, the INFOFRAME messages are exchanged with the shorter

header. This header contains only the Circuit ID associated with the
remote DLS. The Remote Data Link Correlator and the Remote DLC Port
ID are set equal to the Data Link Correlator and the DLC Port ID that
are associated with the origin or target Data Link Switch, dependent
upon the direction of the packet.

3.3. Message Types

The following table lists the protocol data units that are exchanged
between Data Link Switches. All values not listed are reserved for
potential use in follow-on releases.

Command	Function	Hex Value
CANUREACH	Can U Reach Station	x'03'
ICANREACH	I Can Reach Station	x'04'
REACH_ACK	Reach Acknowledgment	x'05'
DGRMFRAME	Datagram Frame (See note)	x'06'
XIDFRAME	XID Frame	x'07'
CONTACT	Contact Remote Station	x'08'
CONTACTED	Remote Station Contacted	x'09'
RESTART_DL	Restart Data Link	x'10'
DL_RESTARTED	Data Link Restarted	x'11'
INFOFRAME	Information (I) Frame	x'0A'
HALT_DL	Halt Data Link	x'0E'
DL_HALTED	Data Link Halted	x'0F'
NETBIOS_NQ	NetBIOS Name Query	x'12'
NETBIOS_NR	NetBIOS Name Recognized	x'13'
DATAFRAME	Data Frame (See note)	x'14'
NETBIOS_ANQ	NetBIOS Add Name Query	x'1A'
NETBIOS_ANR	NetBIOS Add Name Response	x'1B'

Table 1. SSP Message Types

Note: Both the DGRMFRAME and DATAFRAME messages are used to carry
information received by the DLC entity within UI frames. As will
be explained below, the DGRMFRAME message is addressed according
to a pair of Circuit IDs, while the DATAFRAME message is addressed
according to a Data Link ID, being composed of a pair of MAC
addresses and a pair of link SAP addresses. The latter is
employed prior to the establishment of an end-to-end circuit when
Circuit IDs have yet to be established.

For the exchange of NetBIOS control messages, the entire DLC header
is carried as part of the message unit. This includes the MAC
header, with the routing information field padded to 18 bytes, and
the LLC header. The following message types are affected:
NETBIOS_NQ, NETBIOS_NR, NETBIOS_ANQ, NETBIOS_ANR, and DATAFRAME when

being used by NetBIOS systems. The routing information in the DLC
header is not used by the remote Data Link Switch upon receiving the
above five messages.

4. Protocol Specification

   This section provides a description of the Switch-to-Switch
   Protocols. Included is a set of high-level protocol flows and a
   detail set of state transition tables. The states and the protocols
   are described in terms that are intended to be generic to different
   platforms. Emphasis of the technical details is to ensure
   operability of the IBM 6611 with another vendor's implementation.
   Notes are inserted at points where the IBM 6611 performs local
   actions that are specific to the AIX platform upon which it operates.

4.1. Protocol Flow Diagrams

   The switch-to-switch protocols are used to setup and take down
   circuits between a pair of Data Link Switches. Once a circuit is
   established, the end stations on the local networks can employ LLC
   Type 1 (connectionless) protocols. In addition, the end systems can
   establish an end-to-end connection for support of LLC Type 2
   (connection oriented) protocols.

   The term, Data Link, is used in this document to refer to both a
   "logical data link" when supporting Type 1 LLC services, and a "data
   link connection" when supporting Type 2 LLC services. In both cases,
   the Data Link in defined by the concatenation of the destination MAC
   address (DA), the source MAC address (SA), the destination link SAP
   (DSAP) and source link SAP (SSAP).

4.1.1. Connect Protocols

   The following figure depicts the protocol flows that are used for the
   establishment of a circuit between a pair of Data Link Switches,
   followed by the establishment of a connection between the pair of end
   systems. The figure is drawn assuming that the two end systems are
   SNA (the protocol flow for NetBIOS systems is described in a later
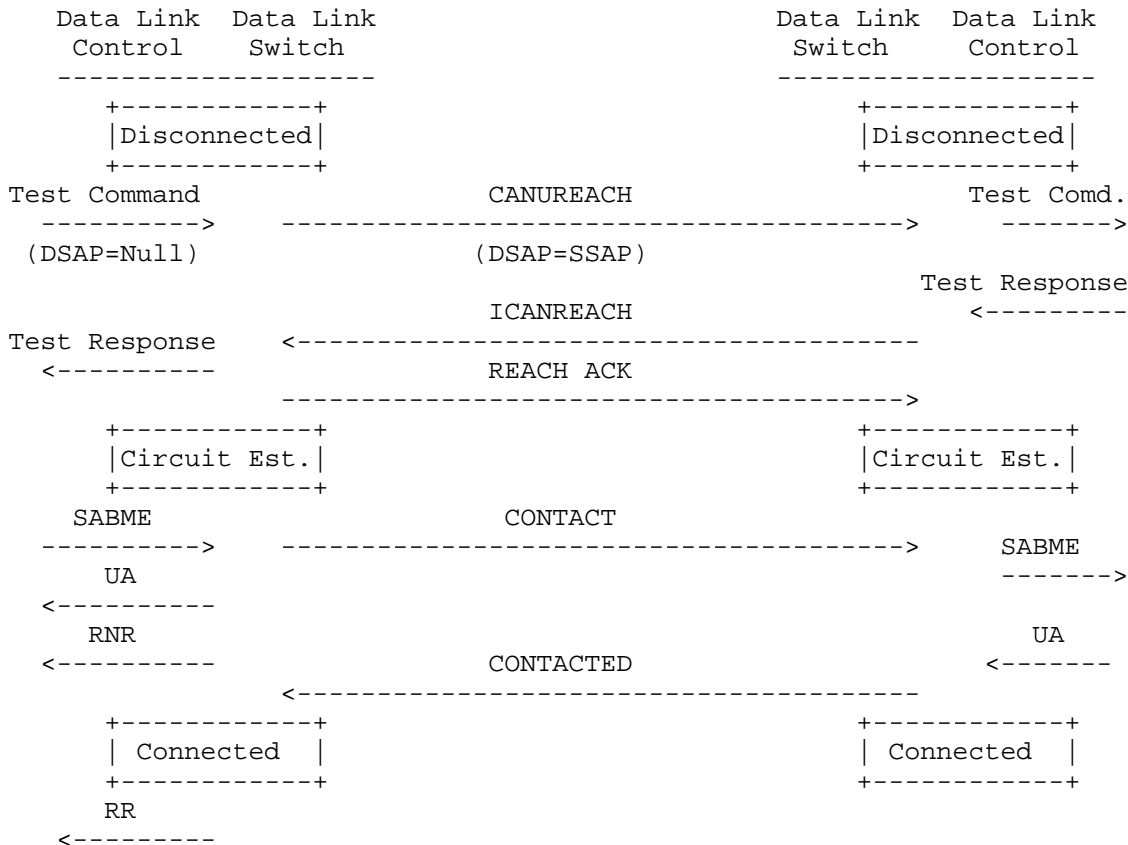   paragraph).

```
   Data Link  Data Link                    Data Link  Data Link
    Control    Switch                        Switch    Control
   -------------------                      -------------------
      +-----------+                            +-----------+
      |Disconnected|                           |Disconnected|
      +-----------+                            +-----------+
Test Command                  CANUREACH                  Test Comd.
  ---------->      --------------------------------------->   ------->
  (DSAP=Null)                (DSAP=SSAP)
                                                        Test Response
                              ICANREACH                    <---------
Test Response    <---------------------------------------
  <---------                  REACH ACK
                 --------------------------------------->
      +-----------+                            +-----------+
      |Circuit Est.|                           |Circuit Est.|
      +-----------+                            +-----------+
    SABME                     CONTACT
  ---------->      --------------------------------------->     SABME
    UA                                                         ------->
  <----------
    RNR                                                          UA
  <---------                  CONTACTED                        <-------
                 <---------------------------------------
      +-----------+                            +-----------+
      | Connected |                            | Connected |
      +-----------+                            +-----------+
    RR
  <---------
```

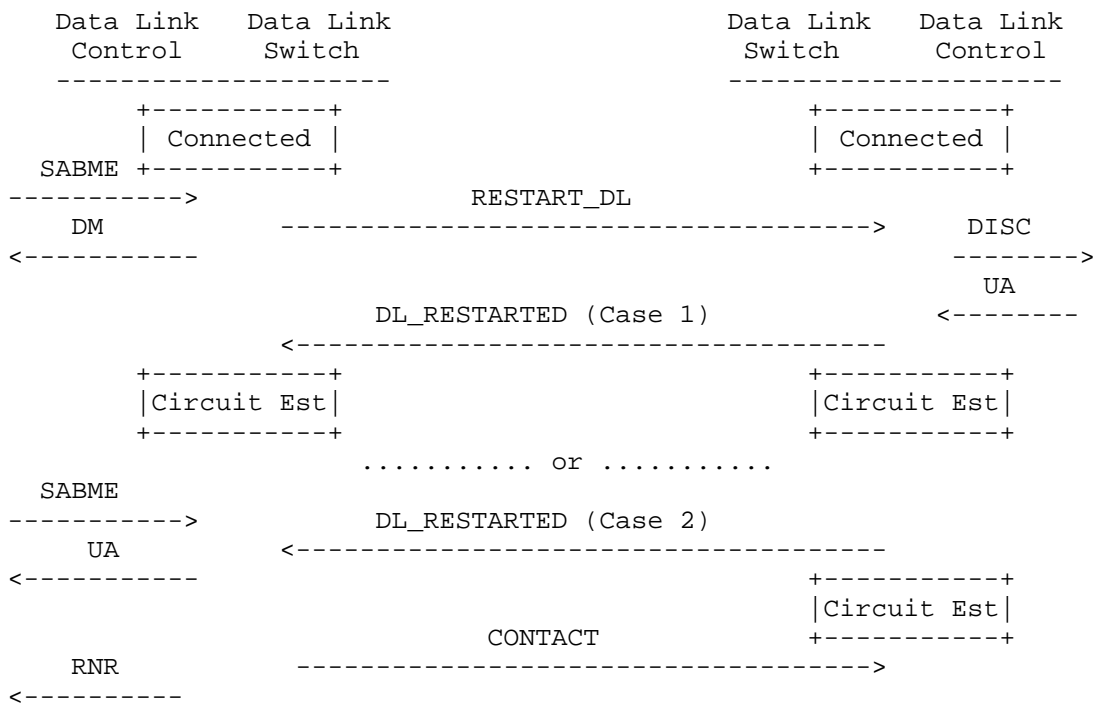   Figure 4. DLS Connect Message Protocols

   Upon receipt of a Test command from the origin station, the origin
   DLS will send a CANUREACH (i.e., can you reach) message to the target
   DLS. If the target DLS is not known to the origin DLS, the CANUREACH
   message is sent to all remote Data Link Switches defined to the
   origin DLS. The receipt of the CANUREACH message causes the target
   DLS to send a Test command searching for the target station. The
   target station will return a Test response, causing the target DLS to
   return an ICANREACH (i.e., I can reach) message to the origin DLS.
   If multiple Data Link Switches can reach the target station, the
   origin DLS will receive multiple ICANREACH messages. The origin DLS
   will select the first message and send a REACH_ACK (i.e., reach
   acknowledgment) message to the selected Data Link Switch. During
   this exchange of messages, both Data Link Switches change states from
   the Disconected state to the Circuit Established state. Once the
   circuit is established, Type-1 frames, such as XID, may be exchanged
   between the origin and target stations.

To establish a connection, the origin station sends a SABME command. Upon receipt of this command, the origin DLS will send a CONTACT message to the target DLS and return a UA response to the origin station. To inhibit traffic flow until the connection is established to the remote station, a RNR supervisory frame is sent to the origin station. The CONTACT message will cause the target DLS to send a SABME command to the target station, which in return will reply with a UA response. Upon receipt of the UA response, the target DLS will send a CONTACTED message to the origin DLS. The origin DLS will now send an RR supervisory frame to the origin station. During this exchange of messages, both Data Link Switches change states from the Circuit Established state to the Connected state.

For NetBIOS end systems, the protocol flows are similar but employ different frames and SSP messages. Instead of using a Test command frame to initiate the circuit, a NetBIOS system will use a Name Query frame. Receipt of a Name Query frame will cause the Data Link Switch to issue a NETBIOS_NQ message instead of the CANUREACH message. In a like fashion, the Test response is replaced with a Name Recognized frame and the ICANREACH message is replaced with a NETBIOS_NR message. As with the SNA protocol flows, the receipt of a NETBIOS_NR message causes the origin Data Link Switch to respond with a REACH_ACK message.

4.1.2. Link Restart Protocols

The following figure depicts the protocol flows that result from restarting the end-to-end connection. This causes the Data Link Switches to terminate the existing connection and to enter the Circuit Established state awaiting the start of a new connection.

```
     Data Link   Data Link                        Data Link   Data Link
      Control      Switch                           Switch     Control
     --------------------                          --------------------
           +-----------+                                +-----------+
           | Connected |                                | Connected |
     SABME +-----------+                                +-----------+
   ----------->                       RESTART_DL
     DM             ------------------------------------>       DISC
   <-----------                                              -------->
                                                                UA
                         DL_RESTARTED (Case 1)               <--------
                  <------------------------------------
           +-----------+                                +-----------+
           |Circuit Est|                                |Circuit Est|
           +-----------+                                +-----------+
     SABME              ........... or ...........
   ----------->             DL_RESTARTED (Case 2)
      UA              <------------------------------------
   <-----------                                         +-----------+
                                                        |Circuit Est|
                             CONTACT                    +-----------+
      RNR             ------------------------------------>
   <----------
```

            Figure 5. DLS Link Restart Message Protocols

   Upon receipt of a SABME command from the origin station, the origin
   DLS will send a RESTART_DL message to the target DLS. A DM response
   is also returned to the origin station and the data link is
   restarted.

   Upon receipt of the RESTART_DL message, the target DLS will issue a
   DISC command to the target station. The target station is expected
   to return a UA response. The target DLS will then restart its data
   link and send an DL_RESTARTED message back to the origin DLS. During
   this exchange of messages, both Data Link Switches change states from
   Connected state to Circuit Established state.

   If the origin station now resends the SABME command, the origin DLS
   will send a CONTACT message to the target DLS. If the SABME command
   is received prior to the receipt of the DL_RESTARTED message (case 2
   in the figure), the CONNECT message is delayed until the DL_RESTARTED
   message is received. The resulting protocol flows at this point
   parallel those given above for the connect sequence.

4.1.3. Disconnect Protocols

   The following figure depicts the protocol flows that result from the
   end system terminating an existing connection. Not only is the
   connection terminated, but the circuit between the Data Link Switches
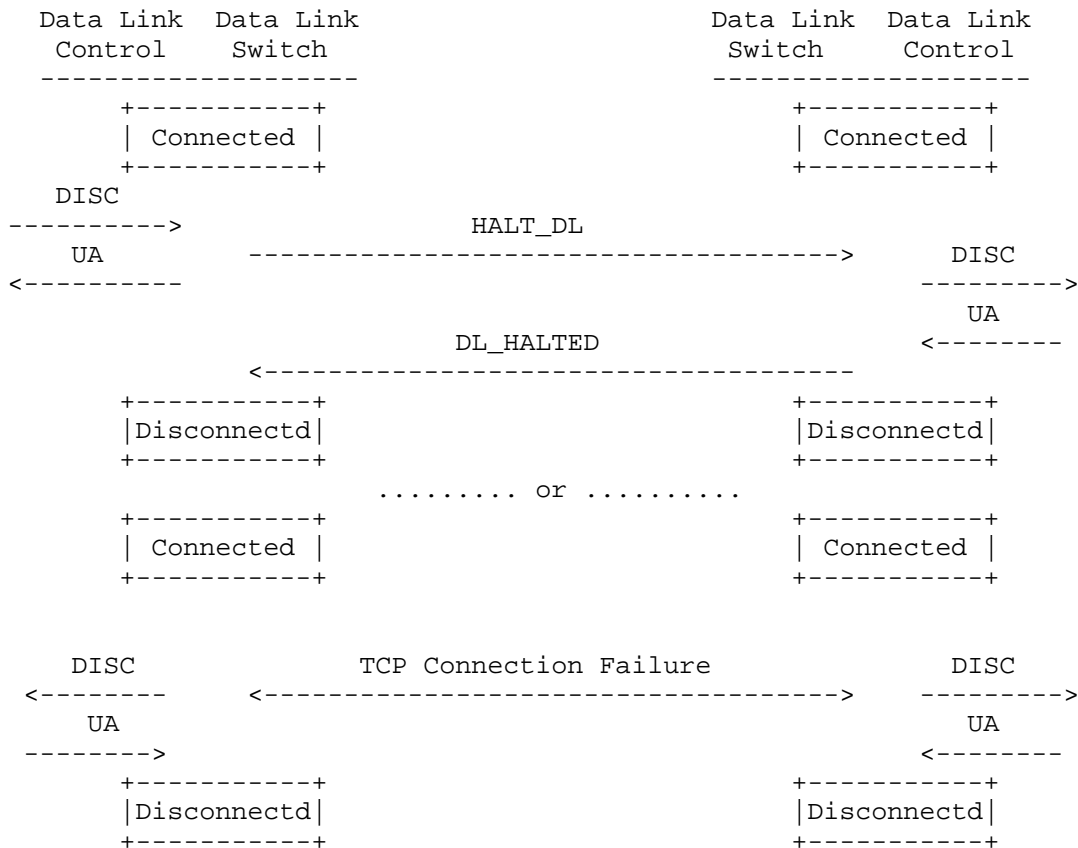   is taken down.

```
   Data Link  Data Link                      Data Link  Data Link
    Control     Switch                          Switch    Control
   -------------------                         -------------------
        +----------+                               +----------+
        | Connected |                              | Connected |
        +----------+                               +----------+
     DISC
   ---------->                  HALT_DL
      UA          ------------------------------------>     DISC
   <----------                                         --------->
                                                           UA
                            DL_HALTED                    <--------
               <------------------------------------
        +----------+                               +----------+
        |Disconnectd|                              |Disconnectd|
        +----------+                               +----------+
                        ......... or ..........
        +----------+                               +----------+
        | Connected |                              | Connected |
        +----------+                               +----------+


     DISC            TCP Connection Failure          DISC
   <--------      <------------------------------------>  --------->
      UA                                                   UA
   -------->                                          <--------
        +----------+                               +----------+
        |Disconnectd|                              |Disconnectd|
        +----------+                               +----------+
```

               Figure 6. DLS Disconnect Message Protocols

   Upon receipt of a DISC command from the origin station, the origin
   DLS will reply with a UA response and issue a HALT_DL message to the
   target DLS. Upon receipt of the HALT_DL message, the target DLS will
   send a DISC command to the target station. The target station will
   then respond with a UA response, causing the target DLS to return a
   DL_HALTED message to the origin DLS. During this exchange of
   messages, both Data Link Switches change states from the Connected
   state to the Disconnected state.

   If the TCP connection between two Data Link Switches fails, all
   connections that are currently multiplexed on the failed TCP
   connection will be taken down. This implies that both Data Link
   Switches will send DISC commands to all the local systems that are
   associated with the failed connections. Upon sending the DISC
   command, the Data Link Switch will enter the DISCONNECT state for
   each circuit.

4.2. DLS State Machine

   The following state tables describe the states for a single
   connection through the Data Link Switch. State information is kept
   for each connection. The initial state for a connection is
   DISCONNECT. The steady state is either CIRCUIT_ESTABLISHED or
   CONNECTED. In the former state, an end-to-end circuit has been
   established allowing the support of Type 1 LLC between the end
   systems. The latter state exists when an end-to-end connection has
   been established for the support of Type 2 LLC services between the
   end systems.

   For SNA, circuit establishment is via the use of IEEE 802.2 Test or
   XID frames. SNA devices send these frames to the null SAP in order
   to determine the source route information in support of bridging.
   Normally SNA devices use SAP x'04', x'08', or x'0C'. Typically the
   SAP would be used to determine if the Test frames should be sent to
   the DLS code in the router. If both bridging and DLS are enabled,
   this allows the product to ensure that SNA frames are not both
   bridged and switched.

   For NetBIOS, circuit establishment is via the Name Query and Name
   Recognized frames. These frames are used for both address resolution
   and source route determination. Normally NetBIOS devices use SAP
   x'F0'.

4.2.1. Data Link Switch States

   The Switch-to-Switch Protocols will be formally defined through a
   single state machine. The following table lists the eleven possible
   states. A separate state machine is employed for each end-to-end
   circuit that is maintained by the Data Link Switch. The three steady
   states are DISCONNECTED, CIRCUIT_ESTABLISHED, and CONNECTED.

```
     State Name              Description
     ----------              -----------
     CIRCUIT_ESTABLISHED     The end-to-end circuit has been
                             established.  At this time LLC Type 1
                             services are available from end-to-end.
     CIRCUIT_PENDING         The target DLS is awaiting a REACH_ACK
                             response to an ICANREACH message.
     CIRCUIT_RESTART         The DLS that originated the reset is
                             awaiting the restart of the data link
                             and the DL_RESTARTED response to a
                             RESTART_DL message.
     CONNECTED               The end-to-end connection has been
                             established thereby allowing LLC Type 2
                             services from end-to-end in addition to
                             LLC Type 1 services.
     CONNECT_PENDING         The origin DLS is awaiting the CONTACTED
                             response to a CONTACT message.
     CONTACT_PENDING         The target DLS is awaiting the
                             DLC_CONTACTED confirmation to a DLC_CONTACT
                             signal (i.e., DLC is waiting for a UA
                             response to an SABME command).
     DISCONNECTED            The initial state with no circuit or
                             connection established, the DLS is awaiting
                             either a CANUREACH, an ICANREACH, a
                             NETBIOS_NQ, or a NETBIOS_NR message.
     DISCONNECT_PENDING      The DLS that originated the disconnect
                             is awaiting the DL_HALTED response to a
                             HALT_DL message.
     HALT_PENDING            The remote DLS is awaiting the DLC_DL_HALTED
                             indication following the DLC_HALT_DL request
                             (i.e., DLC is waiting for a UA response to a
                             DISC command).
     RESTART_PENDING         The remote DLS is awaiting the DLC_DL_HALTED
                             indication following the DLC_HALT_DL request
                             (i.e., DLC is waiting for a UA response to a
                             DISC command), and the restart of the data
                             link.
     RESOLVE_PENDING         The target DLS is awaiting either the
                             DLC_DL_STARTED indication following the
                             DLC_START_DL reqest (i.e., DLC is waiting
                             for a Test response as a result of sending a
                             Test command), or a NB_Name_Recognized
                             frame in response to a NB_Name_Query frame.
```

                      Table 2. Data Link Switch States

   The following figure depicts the events that cause a transition to a
   new state. The resulting action(s) are not explicitly shown. The

DISCONNECT_PENDING state will be entered whenever a DLC error
condition occurs in any of the other states (except RESOLVE_PENDING),
or when a DISC command is received by the DLC.

```
               DLC_RESOLVE_C+----+          +----DLC_ERROR---+
                      |    |         \|/                |
     +------------+   +>+--+--------+   CANUREACH  ++---------+
     | Disconnect +--DL_HALTED-->|Disconnected|------------>|  Resolve   |
     |  Pending   |<+   +------->|            |<-------+   | Pending   |
     +---------+--+ |   |        +-----+------+        |   +-----+------+
      /|\       | HALT_DL|        /|\  |/|\/|\         |          |
  DLC_ERROR     +----+   |      +----+ | |  +------+   |  DLC_DL_STARTED
      |              |   |      |    | | |  |HALT_DL(ts)|  +------+   |
      |              |   |      |    | |ICANREACH|   | HALT_DL(ts)|
      +--HALT_DL(ts)+   |      |    | |      |     | |      |  |
      |         |       |   HALT_DL(ts) | |   HALT_DL(ts) |  |  |
      |         |       |      |     | |      |     | |      |  |
      |    +-RESTART_DL(ts)+----+  | |      |     | |      |  |
      |    |            |      \|/ \|/|     |     | |      | \|/
     +----+---+---+     |     +--------+----+   |  ++-+---------+
     | Contact   |<-CONTACT--+-+  Circuit  |<-REACH_ACK-+   Circuit  |
     | Pending   |          |  | Established|  (DLC not  |   Pending  |
     +-----+------+         |  +----------+-+  contacted)++-+-----+---+
        |    /|\            |    /|\ /|\    |      |       |       |
        |     |             +--+----+  |    |      |       |       |
        |    +-CONTACT--+--+--------+----+------+----------+   REACH_ACK
        |              |  |RESTART_DL(ts)  |         |    (DLC contacted)
    DLC_CONTACTED      |  +------+ |   |      +-------------+   |
        |              |      | | |  | DLC_CONTACTED     | |
     +--------------+-------+ | |  +---------------+   | |
     +-----DL_RESTARTED     | | |                  |  | |
     |  (DLC not contacted) \|/| |            \|/  | \|/
     +-----+------+        +---+-+------+  CONTACTED +-----+------+
     |  Circuit  |<-DLC_RESET---+ Connected |<-----------+  Connect  |
     |  Restart  |           |           |         | Pending  |
     +---------+-+           +-----------+         +-----+------+
       /|\    |             DL_RESTARTED             /|\  |
        |     +---------------(DLC contacted)-------------+   |
        |                                                  |
        +-----------------------DLC_RESET-------------------+
```

        Figure 7. DLS State Transitions (ts = transitional state)

   The DISCONNECT state is the initial state for a new circuit. One end
   station starts the connection via a TEST or XID command (i.e.,
   DLC_RESOLVE_C) or a NetBIOS Name Query command (not explicitly
   shown). Upon receipt, the Data Link Switches exchange a set of
   CANUREACH, ICANREACH and REACH_ACK messages. Upon completion of this
   three-legged exchange, both Data Link Switches will be in the
   CIRCUIT_ESTABLISHED state. Two pending states also exist during this
   exchange. The RESOLVE_PENDING state is entered by the target Data
   Link Switch awaiting a Test response to a Test Command and the

CIRCUIT_PENDING state is entered by the target DLS awaiting the
REACH_ACK reply to an ICANREACH message.

The CIRCUIT_ESTABLISHED state allows for the exchange of LLC Type 1
frames such as the XID exchanges between SNA stations that occurs
prior to the establishment of a connection. Also, datagram traffic
(i.e., UI frames) may be sent and received between the end stations.
These exchanges use the XIDFRAME and DGRMFRAME messages sent between
the Data Link Switches.

In the CIRCUIT_ESTABLISHED state, the receipt of a SABME command
(i.e., DLC_CONTACTED) causes the origin DLS to issue a CONTACT
message, to send an RNR supervisory frame (i.e., DLC_ENTER_BUSY) to
the origin station, and to enter the CONNECT_PENDING state awaiting a
CONTACTED message. The target DLS, upon the receipt of a CONTACT
message, will issue a SABME command (i.e., DLC_CONTACT) and enter the
Contact Pending state. Once the UA response is received (i.e.,
DLC_CONTACTED), the target DLS sends a CONTACTED message and enters
the CONNECTED state. When received, the origin DLS enters the
Connected state and sends an RR supervisory frame (i.e.,
DLC_EXIT_BUSY).

The CONNECTED state is the steady state for normal data flow once a
connection has been established. Information frames (i.e., INFOFRAME
messages) are simply sent back and forth between the end points of
the connection. This is the path that should be optimized for
performance.

The connection is terminated upon the receipt of a DISC frame or
under some other error condition detected by DLC (i.e., DLC_ERROR).
Upon receipt of this indication, the DLS will halt the local data
link, send a HALT_DL message to the remote DLS, and enter the
DISCONNECT_PENDING State. When the HALT_DL frame is received by the
other DLS, the local DLC is halted for this data link, a DL_HALTED
message is returned, and the DISCONNECTED state is entered. Receipt
of this DL_HALTED message causes the other DLS to also enter the
DISCONNECTED state.

The CIRCUIT_RESTART state is entered if one of the Data Link Switches
receives a SABME command (i.e., DLC_RESET) while in the CONNECTED
state. This causes a DM command to be returned to the origin station
and a RESTART_DL message to be sent to the remote Data Link Switch.
This causes the remote data link to be halted and then restarted.
The remote DLS will then send a DL_RESTARTED message back to the
first DLS. The receipt of the DL_RESTARTED message causes the first
DLS to issue a new CONTACT message, assuming that the local DLC has
been contacted (i.e., the origin station has resent the SABME
command). This is eventually responded to by a CONTACTED message.

Following this exchange, both Data Link Switches will return to the
CONNECTED state. If the local DLC has not been contacted, the
receipt of a DL_RESTARTED command causes the Data Link Switch to
enter the CIRCUIT_ESTABLISHED state awaiting the receipt of a SABME
command (i.e., DLC_CONTACTED signal).

In the figure, the transition labeled HALT_DL(ts) represents the
HALT_PENDING state and the transition labeled RESTART_DL(ts)
represents the RESTART_PENDING state. Both these transitional states
have only one input event and only one output action. While in these
states, the Data Link Switch is awaiting responses from the local
station on the adjacent LAN (i.e., a UA response to a DISC command).
Also in the RESTART_PENDING state, the Data Link Switch will attempt
to restart the data link prior to sending a DL_RESTARTED message.
For the IBM 6611 implementation, the start of a data link involves
the exchange of a Test command/response on the adjacent LAN (i.e.,
DLC_START_DL). For other implementations, this additional exchange
may not be required.

4.2.2. State Transition Tables

This section provides a detail representation of the Data Link
Switch, as document by a set of state machines. The first state
machine documents the sending and receiving of SSP messages. Many of
the transitions are dependent upon local signals between the Data
Link Switch entity and one of the DLC entities. These signals and
their definitions are given in the following tables.

```
     Event Name         Description
     ----------         -----------
     DLC_CONTACTED      Contact Indication:  DLC has received an SABME
                        command and will send a UA response, or DLC has
                        received a UA response as a result of sending an
                        SABME command.
     DLC_DGRM           Datagram Indication:  DLC has received a UI frame.
     DLC_ERROR          Error condition indicated by DLC:  Such a
                        condition occurs when a DISC command is received
                        or when DLC experiences an unrecoverable error.
     DLC_INFO           Information Indication:  DLC has received an
                        Information (I) frame.
     DLC_DL_HALTED      Data Link Halted Indication:  DLC has
                        received a UA response to a DISC command.
     DLC_DL_STARTED     Data Link Started Indication:  DLC has
                        received a Test response from the null SAP.
     DLC_RESET          Reset Indication:  DLC has received an SABME
                        command during the time a connection is
                        currently active and has responded with DM.
     DLC_RESOLVE_C      Resolve Command Indication:  DLC has received
                        a Test command addressed to the null SAP, or an
                        XID command addressed to the null SAP.
     DLC_XID            XID Indication:  DLC has received an XID command
                        or response to a non-null SAP.


                   Table 3.  Local DLC Events


     Action Name        Description
     -----------        -----------
     DLC_CONTACT        Contact Station Request:  DLC will send a SABME
                        command.
     DLC_DGRM           Datagram Request:  DLC will send a UI frame.
     DLC_ENTER_BUSY     Enter Link Station Busy:  DLC will send an
                        RNR supervisory frame.
     DLC_EXIT_BUSY      Exit Link Station Busy:  DLC will send an RR
                        supervisory frame.
     DLC_HALT_DL        Halt Data Link Request:  DLC will send a DISC
                        command.
     DLC_INFO           Information Request:  DLC will send an I frame.
     DLC_RESOLVE_R      Resolve Response Request:  DLC will send a
                        Test response or XID response from the null SAP.
     DLC_START_DL       Start Data Link Request:  DLC will send a Test
                        command to the null SAP.
     DLC_XID            XID Request:  DLC will send an XID command or an
                        XID response.


                   Table 4.  Local DLC Actions
```

The Data Link Switch may be described by a state transition table
consisting of eleven states. Each of these states is described below
in terms of the events, actions, and next state for each transition.
If a particular event is not listed for a given state, no action and
no state transition should occur for that event. Any significant
comments concerning the transitions within a given state are given
immediately following the table representing the state.

A separate state machine is maintained by the Data Link Switch for
each end-to-end circuit. The number of circuits that may be
supported by each Data Link Switch is a local implementation option.

4.2.2.1   DISCONNECTED State

Event	Action(s)	Next State
Receive CANUREACH	DLC_START_DL	RESOLVE_PENDING
Receive ICANREACH	Send REACH_ACK, DLC_RESOLVE_R (See note 1)	CIRCUIT_ESTABLISHED
Receive DATAFRAME	DLC_DGRM	
Receive NETBIOS_NQ	DLC_DGRM	RESOLVE_PENDING
Receive NETBIOS_NR	Send REACH_ACK, DLC_DGRM (See note 2)	CIRCUIT_ESTABLISHED
DLC_RESOLVE_C	Send CANUREACH	
DLC_DGRM	If NB_Name_Query: Send NETBIOS_NQ, Else: Send DATAFRAME	

It is assumed that each Data Link Switch will build a set of topology
tables giving the identity of each Data Link Switch that can reach a
specific MAC address or a specific NetBIOS name. This table can be
built based upon the origin address information received within the
CANUREACH message or NETBIOS_NQ message and the target address
information within the ICANREACH message or NETBIOS_NR message. As a
consequence, the amount of search traffic can be kept to a minimum.

Upon receipt of a Test command or XID command to the null SAP (i.e.,
DLC_RESOLVE_C signal from DLC), the Data Link Switch will check the
topology table prior to sending the CANUREACH message. If the target
MAC address is in the table, the CANUREACH message will be sent to
only those Data Link Switches that are known to be able to reach the
given MAC address. If the MAC address is not in the table, the
CANUREACH message will be sent to all known Data Link Switches.
Since the destination link SAP (DSAP) value is null, the Target Link
SAP field in the CANUREACH message header is set equal to the Origin

Link SAP value.

Upon receipt of a NB_Name_Query the Data Link Switch will check the
topology table prior to sending the NETBIOS_NQ message. If the
target NetBIOS name is in the table, the NETBIOS_NQ message will be
sent to only those Data Link Switches that are known to be able to
reach the given NetBIOS name. If the NetBIOS name is not in the
table, the NETBIOS_NQ message will be sent to all known Data Link
Switches.

For SNA, the DISCONNECTED state is exited upon receipt of a CANUREACH
message by a prospective target Data Link Switch, or upon receipt of
an ICANREACH message by the origin Data Link Switch. In the former
case, the Data Link Switch will issue a Test command to the target
station (i.e., DLC_START_DL signal is presented to DLC). In the
later case, a Test response is sent to the origin station (i.e.,
DLC_RESOLVE_R will be issued) and a REACH_ACK message will be
returned to the target Data Link Switch.

    Note 1- The IBM 6611 will not send a Test response, but will send
    a Test command to the station that originated the resolve
    procedure (i.e., a DLC_START_DL will be issued) in order to start
    the data link.

For NetBIOS, the DISCONNECTED state is exited upon the receipt of a
NETBIOS_NQ message by the prospective target Data Link Switch, or
upon the receipt of a NETBIOS_NR message by the origin Data Link
Switch. In the former case, the Data Link Switch will send a
NB_Name_Query frame. In the later case, the Data Link Switch will
send a NB_Name_Recognized frame to the origin station and a REACH_ACK
message will be returned to the target Data Link Switch.

    Note 2- The IBM 6611 will also send a Test command (i.e., a
    DLC_START_DL will be issued) to the station that originated the
    name resolution in order to start the data link.

4.2.2.2   RESOLVE_PENDING State

```
   Event                   Action(s)                Next State
   -----                   ---------                ----------
   Receive DATAFRAME       DLC_DGRM
   DLC_DL_STARTED          Send ICANREACH           CIRCUIT_PENDING
   DLC_ERROR                                        DISCONNECTED
   DLC_DGRM                If NB_Name_Recognized: If
                           Send NETBIOS_NR        NB_Name_Recognized:
                           (See note),            CIRCUIT_PENDING
                           Else:
                           Send DATAFRAME
```

The RESOLVE_PENDING state is entered upon receipt of a CANUREACH
message or a NETBIOS_NQ message by the target DLS. In the former
case, a data link is started, causing a Test command to be sent by
the DLC. In the later case, a NB_Name_Query frame is sent. This
frame is directed to a group MAC address.

Any CANUREACH messages received in the RESOLVE_PENDING state will be
responded to if a DLC_DL_STARTED signal is received. The Data Link
Switch may also update its topology information based upon the origin
MAC address information in each CANUREACH message.

Upon the receipt of a DLC_DL_STARTED signal in the RESOLVE_PENDING
state, the Data Link Switch may update its topology table base upon
the remote MAC address information. The ICANREACH message should be
returned to all Data Link Switches that had sent a CANUREACH message.
In a similar fashion, the Data Link Switch may update its topology
table upon the receipt of a NB_Name_Recognized frame and a NETBIOS_NR
message will be returned to all Data Link Switches that have sent a
NETBIOS_NQ message.

The RESOLVE_PENDING state is exited once the data link has been
started (i.e., a DLC_DL_STARTED signal is received as a result of a
Test response received by the DLC) or a NB_Name_Recognized frame is
received (i.e., a DLC_DGRM signal is received). The target Data Link
Switch will then enter the CIRCUIT_PENDING state.

   Note: The IBM 6611 will also send a Test command in order to
   start the data link to the station that responded to the Name
   Query frame (i.e., a DLC_START_DL will be issued).

4.2.2.3   CIRCUIT_PENDING State

```
   Event                   Action(s)           Next State
   -----                   ---------           ----------
   Receive CONTACT         DLC_CONTACT         CONTACT_PENDING
   Receive HALT_DL         DLC_HALT_DL         HALT_PENDING
   Receive REACH_ACK       If Connected:       If Connected:
                           Send CONTACT        CONNECT_PENDING,
                                               else: CIRCUIT_ESTABLISHED
   Receive XIDFRAME        DLC_XID
   Receive DGRMFRAME       DLC_DGRM
   Receive DATAFRAME       DLC_DGRM
   DLC_CONTACTED           DLC_ENTER_BUSY
   DLC_ERROR               Send HALT_DL        DISCONNECT_PENDING
   DLC_XID                 Send XIDFRAME
   DLC_DGRM                Send DGRMFRAME
```

   The CIRCUIT_PENDING state is entered by the target Data Link Switch
   following the sending of an ICANREACH message or the sending of a
   NETBIOS_NR message. In this state it is awaiting the reception of a
   REACH_ACK message from the origin Data Link Switch. If a connection
   does not exist with the target station (i.e., the normal case), the
   Data Link Switch will enter the CIRCUIT_ESTABLISHED state.

   If the target Data Link Switch happens to receive a SABME command
   from the target station while in the CIRCUIT_PENDING state (i.e., a
   DLC_CONTACTED signal received from the DLC), the reception of the
   REACH_ACK message will cause the Data Link Switch to enter the
   CONNECT_PENDING state and to send a CONTACT message to the other Data
   Link Switch. Thus the target Data Link Switch has assumed the role
   of the origin Data Link Switch.

4.2.2.4   CONNECT_PENDING State

   Event   Action(s)   Next State
   -----   ---------   ----------
   Receive CONTACTED   DLC_EXIT_BUSY   CONNECTED
   Receive HALT_DL   DLC_HALT_DL   HALT_PENDING
   Receive DGRMFRAME   DLC_DGRM
   Receive DATAFRAME   DLC_DGRM
   DLC_RESET   Send RESTART_DL (See note) CIRCUIT_RESTART
   DLC_ERROR   Send HALT_DL   DISCONNECT_PENDING
   DLC_DGRM   Send DGRMFRAME

   The CONNECT_PENDING state is entered by the origin Data Link Switch
   when a DLC_CONTACTED signal has been received from the DLC (i.e., a
   SABME command has been received). A CONTACT message is then issued.
   The state is exited upon the receipt of a CONTACTED message from the
   target Data Link Switch. If a DLC_RESET signal is received, the
   local data link is restarted and a RESTART_DL message is sent to the
   remote DLS.

      Note: The IBM 6611 will also send a Test command in order to
      restart the data link to the station that sent the SABME command
      (i.e., a DLC_START_DL will be issued).

4.2.2.5   CIRCUIT_ESTABLISHED State

```
Event                   Action(s)                    Next State
-----                   ---------                    ----------
Receive CONTACT         DLC_CONTACT                  CONTACT_PENDING
Receive HALT_DL         DLC_HALT_DL                  HALT_PENDING
Receive XIDFRAME        DLC_XID
Receive DGRMFRAME       DLC_DGRM
Receive DATAFRAME       DLC_DGRM
DLC_CONTACTED           Send CONTACT                 CONNECT_PENDING
                        DLC_ENTER_BUSY
DLC_ERROR               Send HALT_DL                 DISCONNECT_PENDING
DLC_DGRM                Send DGRMFRAME
DLC_XID                 Send XIDFRAME
```

  The CIRCUIT_ESTABLISHED state is entered by the origin Data Link
  Switch from the DISCONNECTED state, and by the target Data Link
  Switch from the CIRCUIT_PENDING state. The state is exited when a
  connection is started (i.e., DLC receives a SABME command). The next
  state is CONTACT_PENDING for the target Data Link Switch and
  CONNECT_PENDING for the origin Data Link Switch.

4.2.2.6   CONTACT_PENDING State

```
Event                   Action(s)                    Next State
-----                   ---------                    ----------
Receive HALT_DL         DLC_HALT_DL                  HALT_PENDING
Receive RESTART_DL      DLC_HALT_DL                  RESTART_PENDING
Receive DGRMFRAME       DLC_DGRM
Receive DATAFRAME       DLC_DGRM
DLC_CONTACTED           Send CONTACTED               CONNECTED
DLC_ERROR               Send HALT_DL                 DISCONNECT_PENDING
DLC_DGRM                Send DGRMFRAME
```

  The CONTACT_PENDING state is entered by the target Data Link Switch
  upon the receipt of a CONTACT message. This causes the Data Link
  Switch to issue a DLC_CONTACT signal to the DLC (i.e., DLC sends a
  SABME command). This state is then exited upon the receipt of a
  DLC_CONTACTED signal from the DLC (i.e., a UA response received).

  If a RESTART_DL message is received, indicating that the remote Data
  Link Switch has received a DLC_RESET signal, the local Data Link
  Switch will send a DISC command frame on the adjacent LAN (i.e.,
  DLC_HALT_DL signal) and enter the RESTART_PENDING state.

4.2.2.7   CONNECTED State

```
  Event                 Action(s)                    Next State
  -----                 ---------                    ----------
  Receive HALT_DL       DLC_HALT_DL                  HALT_PENDING
  Receive RESTART_DL    DLC_HALT_DL                  RESTART_PENDING
  Receive DGRMFRAME     DLC_DGRM
  Receive INFOFRAME     DLC_INFO
  Receive DATAFRAME     DLC_DGRM
  DLC_RESET             Send RESTART_DL (See note)   CIRCUIT_RESTART
  DLC_ERROR             Send HALT_DL                 DISCONNECT_PENDING
  DLC_DGRM              Send DGRMFRAME
  DLC_INFO              Send INFOFRAME
```

 The CONNECTED state is entered by the origin Data Link Switch from
 the CONNECT_PENDING state upon the receipt of a CONTACTED message.
 The CONNECTED state is entered by the target Data Link Switch from
 the CONTACT_PENDING state upon the receipt of a DLC_CONTACTED signal.
 At this time, the target Data Link Switch will return a CONTACTED
 message to the origin Data Link Switch.

 The CONNECTED state is exited usually under one of two conditions: a
 DLC_ERROR signal received from the DLC (e.g., a DISC command received
 by the local DLC), or a HALT_DL message received from the other Data
 Link Switch (e.g., a DISC command received by the remote DLC).

 A SABME command (i.e., a DLC_RESET signal) received by either Data
 Link Switch will also cause the two Data Link Switches to leave the
 CONNECTED state and eventually restart a new circuit.

    Note: The IBM 6611 will also send a Test command in order to
    restart the data link to the station that sent the SABME command
    (i.e., a DLC_START_DL will be issued).

 Following the receipt of a reset signal, the Data Link Switch will
 send a RESTART_DL message to the other Data Link Switch and will
 enter the CIRCUIT_RESTART state. Upon the receipt of the RESTART_DL
 message, the remote Data Link Switch will send a DISC command (i.e.,
 DLC_HALT_DL signal) and enter the RESTART_PENDING state.

4.2.2.8   CIRCUIT_RESTART State

```
  Event                 Action(s)           Next State
  -----                 ---------           ----------
  Receive DL_RESTARTED  If Connected:       If Connected:
                        Send CONTACT        CONNECT_PENDING,
                                            else: CIRCUIT_ESTABLISHED
  Receive DATAFRAME     DLC_DGRM
```

```
    DLC_ERROR                Send HALT_DL           DISCONNECT_PENDING
    DLC_DGRM                 Send DATAFRAME
```

   The CIRCUIT_RESTART state is entered if a DLC_RESET signal is
   received from the local DLC. This was caused by the receipt of a
   SABME command while a connection was currently active. A DM response
   will be issued to the SABME command and the Data Link Switch will
   attempt to restart the end-to- end circuit.

   The CIRCUIT_RESTART state is exited through one of two transitions.
   The next state depends upon the time the local DLC has reached the
   contacted state (i.e., a DLC_CONTACTED signal is presented) relative
   to the receipt of the DL_RESTARTED message. This signal is caused by
   the origin station resending the SABME command that initially caused
   the DATA Link Switch to enter the CIRCUIT_RESTART state. The two
   cases are as follows:

        1) DL_RESTARTED message received before the
        DLC_CONTACTED signal- In this case, the
        CIRCUIT_ESTABLISHED state is entered.

        2) DL_RESTARTED message received after the
        DLC_CONTACTED signal- In this case, the
        CONNECT_PENDING state is entered.

4.2.2.9   DISCONNECT_PENDING State

```
    Event                    Action(s)              Next State
    -----                    ---------              ----------
    Receive DL_HALTED                               DISCONNECTED
    Receive HALT_DL          Send DL_HALTED
    Receive DATAFRAME        DLC_DGRM
    DLC_DGRM                 Send DATAFRAME
```

   The DISCONNECT_PENDING state is entered when a DLC_ERROR signal is
   received from the local DLC. Upon receipt of this signal, a HALT
   message is sent. Once an DL_HALTED message is received, the state is
   exited, and the Data Link Switch enters the DISCONNECTED state.

4.2.2.10   RESTART_PENDING State

```
    Event                    Action(s)              Next State
    -----                    ---------              ----------
    Receive DATAFRAME        DLC_DGRM
    DLC_DL_HALTED (See note) Send DL_RESTARTED      CIRCUIT_ESTABLISHED
    DLC_ERROR                Send HALT_DL           DISCONNECT_PENDING
    DLC_DGRM                 Send DATAFRAME
```

The RESTART_PENDING state is entered upon the receipt of a RESTART_DL
message from the remote DLS while the local Data Link Switch is in
either the CONTACT_PENDING state or the CONNECTED state. These cause
the local DLC to issue a DISC command. Upon the receipt of the UA
response (DLC_DL_HALTED), the data link is restarted, a DL_RESTARTED
message is returned to the remote DLS, and the CIRCUIT_ESTABLISHED
state is entered.

   Note: The IBM 6611 will send a Test command in order to restart
   the data link to the target station (i.e., a DLC_START_DL will be
   issued) prior to sending the DL_RESTARTED message.

4.2.2.11 HALT_PENDING State

Event	Action(s)	Next State
Receive DATAFRAME	DLC_DGRM	
DLC_DL_HALTED	Send DL_HALTED	DISCONNECTED
DLC_ERROR	Send DL_HALTED	DISCONNECTED
DLC_DGRM	Send DATAFRAME	

The HALT_PENDING state is entered upon the receipt of a HALT_DL
message. This causes the local DLC to issue a DISC command. Upon
the receipt of the UA response (DLC_DL_HALTED), a DL_HALTED message
is returned to the remote DLS and the DISCONNECTED state is entered.

4.3. NetBIOS Datagrams

The NetBIOS protocols use a number of UI frames for directory
services and the transmission of datagrams. Most of these frames are
directed to a group MAC address (GA) with the routing information
field indicating spanning tree explorer (STE). Two of the frames,
NB_Add_Name_Response and NB_Status_Response, are directed to a
specific MAC address with the routing information field indicating a
specifically routed frame (SRF). The handling of these frames is
summarized in the following table.

Event	Action(s)	Comment
DLC_DGRM (NB Group Address): NB_Add_Name_Query	Send NETBIOS_ANQ	Transmitted to all remote DLS
DLC_DGRM (Specific Address): NB_Add_Name_Response	Send NETBIOS_ANR	Transmitted to specific DLS
DLC_DGRM (Specific Address): NB_Status_Response	Send DATAFRAME	Transmitted to all remote DLS
DLC_DGRM (NB Group Address): NB_Name_in_Conflict, NB_Add_Group_Name_Query,	Send DATAFRAME	Transmitted to all remote DLS

```
        NB_Datagram,
        NB_Datagram_Broadcast,
        NB_Status_Query,
        NB_Terminate_Trace
```

                   Table 5. NetBIOS DLC Frames

The above actions do not apply in the following states:
CIRCUIT_ESTABLISHED, CONTACT_PENDING, CONNECT_PENDING, CONNECTED, and
CIRCUIT_PENDING. The handling of the remaining two UI frames used by
NetBIOS systems, NB_Name_Query and NB_Name_Recognized, are documented
as part of the DLS state machine in the previous section (i.e.,
DISCONNECTED and RESOLVE_PENDING states). Furthermore, the handling
of NetBIOS datagrams (i.e., NB_Datagram) sent to a specific MAC
address is also governed by the DLS state machine.

   Note: The IBM 6611 will also issue Test frames during the
   exchange of the NetBIOS, NB_Name_Query and NB_Name_Recognized.
   This exchange of protocol data units occurs during the start of a
   data link and is used to determine the routing information. Most
   other implementations of NetBIOS will use the
   NB_Name_Query/NB_Name_Recognized exchange to determine routes in
   conjunction with resolving the NetBIOS names. These differences
   are not reflected in the SSP protocols.

The handling of the NetBIOS specific SSP messages is given in the
following table.

```
   Event               Action(s)                 Comment
   -----               ---------                 -------
   NETBIOS_ANQ         DLC_DGRM:                 Routed STE
                           NB_Add_Name_Query     (NB Group Address)
   NETBIOS_ANR         DLC_DGRM:                 Routed SRF
                           NB_Add_Name_Response  (Specific MAC Address)
   NETBIOS_NQ          DLC_DGRM:                 Routed STE
                           NB_Name_Query         (NB Group Address)
   NETBIOS_NR          DLC_DGRM:                 Routed SRF
                           NB_Name_Recognized    (Specific MAC Address)
   DATAFRAME           DLC_DGRM                  Routed STE
                                                 (If NB_Status_Response:
                                                 Specific MAC Address
                                                 Else: NB Group Address)
```

                  Table 6. NetBIOS SSP Messages

The above actions apply to all DLS states. The handling of NetBIOS
datagrams sent within DGRMFRAME messages is governed by the DLS state
machine. The DGRMFRAME message type is employed instead of the

DATAFRAME message type once the end-to-end circuit has been
established. At that time, the message is addressed according to the
pair of Circuit IDs in the message header instead of relying upon the
MAC address information in the token ring header.

Acknowledgments

   Randall Campbell, David Miller, Gene Cox, Ravi Periasamy, and The
   Ghost of Christmas Past.

References

   1) ISO 8802-2/IEEE Std 802.2 International Standard,
      Information Processing Systems, Local Area Networks, Part 2:
      Logical Link Control, December 31, 1989

   2) The NETBIOS Frames Protocol, IBM Local Area Technical
      Reference, SC30-3383-03, Chapter 5, December 1990

   3) ISO/IEC DIS 10038 DAM 2, MAC Bridging, Source Routing
      Supplement, December 1991

Security Considerations

   Security issues are not discussed in this memo.

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   Note: Any questions or comments relative to the contents of this RFC
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   the handling of responses.