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APPN/HPR in IP Networks
APPN Implementers' Workshop Closed Pages Document

Status of this Memo

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1.0 Introduction

The APPN Implementers' Workshop (AIW) is an industry-wide consortium of networking vendors that develops Advanced Peer-to-Peer Networking(R) (APPN(R)) standards and other standards related to Systems Network Architecture (SNA), and facilitates high quality, fully interoperable APPN and SNA internetworking products. The AIW approved Closed Pages (CP) status for the architecture in this document on December 2, 1997, and, as a result, the architecture was added to the AIW architecture of record. A CP-level document is sufficiently detailed that implementing products will be able to interoperate; it contains a clear and complete specification of all necessary changes to the architecture of record. However, the AIW has procedures by which the architecture may be modified, and the AIW is open to suggestions from the internet community.

The architecture for APPN nodes is specified in "Systems Network Architecture Advanced Peer-to-Peer Networking Architecture Reference" [1]. A set of APPN enhancements for High Performance Routing (HPR) is specified in "Systems Network Architecture Advanced Peer-to-Peer Networking High Performance Routing Architecture Reference, Version 3.0" [2]. The formats associated with these architectures are specified in "Systems Network Architecture Formats" [3]. This memo assumes the reader is familiar with these specifications.

This memo defines a method with which HPR nodes can use IP networks for communication, and the enhancements to APPN required by this method. This memo also describes an option set that allows the use of the APPN connection network model to allow HPR nodes to use IP networks for communication without having to predefine link connections.

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1.1 Requirements

The following are the requirements for the architecture specified in this memo:

1. Facilitate APPN product interoperation in IP networks by documenting agreements such as the choice of the logical link control (LLC).

2. Reduce system definition (e.g., by extending the connection network model to IP networks) -- Connection network support is an optional function.

3. Use class of service (COS) to retain existing path selection and transmission priority services in IP networks; extend transmission priority function to include IP networks.

4. Allow customers the flexibility to design their networks for low cost and high performance.

5. Use HPR functions to improve both availability and scalability over existing integration techniques such as Data Link Switching (DLSw) which is specified in RFC 1795 [4] and RFC 2166 [5].

2.0 IP as a Data Link Control (DLC) for HPR

This memo specifies the use of IP and UDP as a new DLC that can be supported by APPN nodes with the three HPR option sets: HPR (option set 1400), Rapid Transport Protocol (RTP) (option set 1401), and Control Flows over RTP (option set 1402). Logical Data Link Control (LDLC) Support (option set 2006) is also a prerequisite.

RTP is a connection-oriented, full-duplex protocol designed to transport data in high-speed networks. HPR uses RTP connections to transport SNA session traffic. RTP provides reliability (i.e., error recovery via selective retransmission), in-order delivery (i.e., a first-in-first-out [FIFO] service provided by resequencing data that arrives out of order), and adaptive rate-based (ARB) flow/congestion control. Because RTP provides these functions on an end-to-end basis, it eliminates the need for these functions on the link level along the path of the connection. The result is improved overall performance for HPR. For a more complete description of RTP, see Appendix F of [2].

This new DLC (referred to as the native IP DLC) allows customers to take advantage of APPN/HPR functions such as class of service (COS) and ARB flow/congestion control in the IP environment. HPR links established over the native IP DLC are referred to as HPR/IP links.

The following sections describe in detail the considerations and enhancements associated with the native IP DLC.

2.1 Use of UDP and IP

The native IP DLC will use the User Datagram Protocol (UDP) defined in RFC 768 [6] and the Internet Protocol (IP) version 4 defined in RFC 791 [7].

Typically, access to UDP is provided by a sockets API. UDP provides an unreliable connectionless delivery service using IP to transport messages between nodes. UDP has the ability to distinguish among multiple destinations within a given node, and allows port-number-based prioritization in the IP network. UDP provides detection of corrupted packets, a function required by HPR. Higher-layer protocols such as HPR are responsible for handling problems of message loss, duplication, delay, out-of-order delivery, and loss of connectivity. UDP is adequate because HPR uses RTP to provide end-to-end error recovery and in-order delivery; in addition, LDLC detects loss of connectivity. The Transmission Control Protocol (TCP) was not chosen for the native IP DLC because the additional services provided by TCP such as error recovery are not needed. Furthermore, the termination of TCP connections would require additional node resources (control blocks, buffers, timers, and retransmit queues) and would, thereby, reduce the scalability of the design.

The UDP header has four two-byte fields. The UDP Destination Port is a 16-bit field that contains the UDP protocol port number used to demultiplex datagrams at the destination. The UDP Source Port is a 16-bit field that contains the UDP protocol port number that specifies the port to which replies should be sent when other information is not available. A zero setting indicates that no source port number information is being provided. When used with the native IP DLC, this field is not used to convey a port number for replies; moreover, the zero setting is not used. IANA has registered port numbers 12000 through 12004 for use in these two fields by the native IP DLC; use of these port numbers allows prioritization in the IP network. For more details of the use of these fields, see 2.6.1, "IP Prioritization" on page 28.

The UDP Checksum is a 16-bit optional field that provides coverage of the UDP header and the user data; it also provides coverage of a pseudo-header that contains the source and destination IP addresses. The UDP checksum is used to guarantee that the data has arrived intact at the intended receiver. When the UDP checksum is set to

zero, it indicates that the checksum was not calculated and should not be checked by the receiver. Use of the checksum is recommended for use with the native IP DLC.

IP provides an unreliable, connectionless delivery mechanism. The IP protocol defines the basic unit of data transfer through the IP network, and performs the routing function (i.e., choosing the path over which data will be sent). In addition, IP characterizes how "hosts" and "gateways" should process packets, the circumstances under which error messages are generated, and the conditions under which packets are discarded. An IP version 4 header contains an 8-bit Type of Service field that specifies how the datagram should be handled. As defined in RFC 1349 [8], the type-of-service byte contains two defined fields. The 3-bit precedence field allows senders to indicate the priority of each datagram. The 4-bit type of service field indicates how the network should make tradeoffs between throughput, delay, reliability, and cost. The 8-bit Protocol field specifies which higher-level protocol created the datagram. When used with the native IP DLC, this field is set to 17 which indicates the higher-layer protocol is UDP.

2.2 Node Structure

Figure 1 on page 6 shows a possible node functional decomposition for transport of HPR traffic across an IP network. There will be variations in different platforms based on platform characteristics.

The native IP DLC includes a DLC manager, one LDLC component for each link, and a link demultiplexor. Because UDP is a connectionless delivery service, there is no need for HPR to activate and deactivate lower-level connections.

The DLC manager activates and deactivates a link demultiplexor for each port and an instance of LDLC for each link established in an IP network. Multiple links (e.g., one defined link and one dynamic link for connection network traffic) may be established between a pair of IP addresses. Each link is identified by the source and destination IP addresses in the IP header and the source and destination service access point (SAP) addresses in the IEEE 802.2 LLC header (see 6.0, "Appendix - Packet Format" on page 37); the link demultiplexor passes incoming packets to the correct instance of LDLC based on these identifiers. Moreover, the IP address pair associated with an active link and used in the IP header may not change.

LDLC also provides other functions (for example, reliable delivery of Exchange Identification [XID] commands). Error recovery for HPR RTP packets is provided by the protocols between the RTP endpoints.

The network control layer (NCL) uses the automatic network routing (ANR) information in the HPR network header to either pass incoming packets to RTP or an outgoing link.

All components are shown as single entities, but the number of logical instances of each is as follows:

- DLC manager -- 1 per node
- LDLC -- 1 per link
- Link demultiplexor -- 1 per port
- NCL -- 1 per node (or 1 per port for efficiency)
- RTP -- 1 per RTP connection
- UDP -- 1 per port
- IP -- 1 per port

Products are free to implement other structures. Products implementing other structures will need to make the appropriate modifications to the algorithms and protocol boundaries shown in this document.

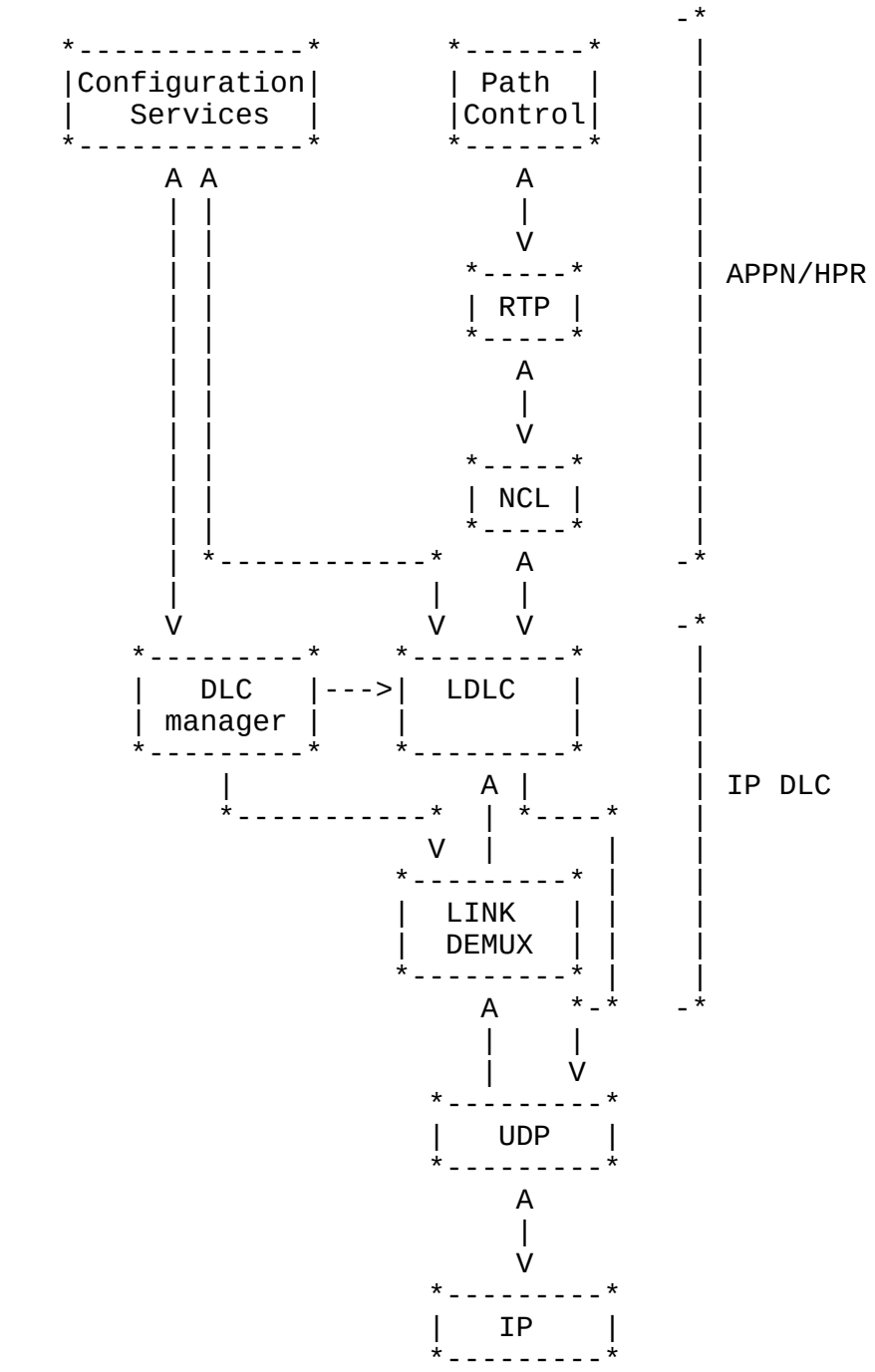


Figure 1. HPR/IP Node Structure

2.3 Logical Link Control (LLC) Used for IP

Logical Data Link Control (LDLC) is used by the native IP DLC. LDLC is defined in [2]. LDLC uses a subset of the services defined by IEEE 802.2 LLC type 2 (LLC2). LDLC uses only the TEST, XID, DISC, DM, and UI frames.

LDLC was defined to be used in conjunction with HPR (with the HPR Control Flows over RTP option set 1402) over reliable links that do not require link-level error recovery. Most frame loss in IP networks (and the underlying frame networks) is due to congestion, not problems with the facilities. When LDLC is used on a link, no link-level error recovery is available; as a result, only RTP traffic is supported by the native IP DLC. Using LDLC eliminates the need for LLC2 and its associated cost (adapter storage, longer path length, etc.).

2.3.1 LDLC Liveness

LDLC liveness (using the LDLC TEST command and response) is required when the underlying subnetwork does not provide notification of connection outage. Because UDP is connectionless, it does not provide outage notification; as a result, LDLC liveness is required for HPR/IP links.

Liveness should be sent periodically on active links except as described in the following subsection when the option to reduce liveness traffic is implemented. The default liveness timer period is 10 seconds. When the defaults for the liveness timer and retry timer (15 seconds) are used, the period between liveness tests is smaller than the time required to detect failure (retry count multiplied by retry timer period) and may be smaller than the time for liveness to complete successfully (on the order of round-trip delay). When liveness is implemented as specified in the LDLC finite-state machine (see [2]) this is not a problem because the liveness protocol works as follows: The liveness timer is for a single link. The timer is started when the link is first activated and each time a liveness test completes successfully. When the timer expires, a liveness test is performed. When the link is operational, the period between liveness tests is on the order of the liveness timer period plus the round-trip delay.

For each implementation, it is necessary to check if the liveness protocol will work in a satisfactory manner with the default settings for the liveness and retry timers. If, for example, the liveness timer is restarted immediately upon expiration, then a different default for the liveness timer should be used.

2.3.1.1 Option to Reduce Liveness Traffic

In some environments, it is advantageous to reduce the amount of liveness traffic when the link is otherwise idle. (For example, this could allow underlying facilities to be temporarily deactivated when not needed.) As an option, implementations may choose not to send liveness when the link is idle (i.e., when data was neither sent nor received over the link while the liveness timer was running). (If the implementation is not aware of whether data has been received, liveness testing may be stopped while data is not being sent.) However, the RTP connections also have a liveness mechanism which will generate traffic. Some implementations of RTP will allow setting a large value for the ALIVE timer, thus reducing the amount of RTP liveness traffic.

If LDLC liveness is turned off while the link is idle, one side of the link may detect a link failure much earlier than the other. This can cause the following problems:

- If a node that is aware of a link failure attempts to reactivate the link, the partner node (unaware of the link failure) may reject the activation as an unsupported parallel link between the two ports.

- If a node that is unaware of an earlier link failure sends data (including new session activations) on the link, it may be discarded by a node that detected the earlier failure and deactivated the link. As a result, session activations would fail.

The mechanisms described below can be used to remedy these problems. These mechanisms are needed only in a node not sending liveness when the link is idle; thus, they would not be required of a node not implementing this option that just happened to be adjacent to a node implementing the option.

- (Mandatory unless the node supports multiple active defined links between a pair of HPR/IP ports and supports multiple active dynamic links between a pair of HPR/IP ports.) Anytime a node rejects the activation of an HPR/IP link as an unsupported parallel link between a pair of HPR/IP ports (sense data X’10160045’ or X’10160046’), it should perform liveness on any active link between the two ports that is using a different SAP pair. Thus, if the activation was not for a parallel link but rather was a reactivation because one of these active links had failed, the failed link will be detected. (If the SAP pair for the link being activated matches the SAP pair for an active link, a liveness test would succeed because the adjacent node would

respond for the link being activated.) A simple way to implement this function is for LDLC, upon receiving an activation XID, to run liveness on all active links with a matching IP address pair and a different SAP pair.

- (Mandatory) Anytime a node receives an activation XID with an IP address pair and a SAP pair that match those of an active link, it should deactivate the active link and allow it to be reestablished. A timer is required to prevent stray XIDs from deactivating an active link.

- (Recommended) A node should attempt to reactivate an HPR/IP link before acting on an LDLC-detected failure. This mechanism is helpful in preventing session activation failures in scenarios where the other side detected a link failure earlier, but the network has recovered.

2.4 IP Port Activation

The node operator (NO) creates a native IP DLC by issuing DEFINE_DLC(RQ) (containing customer-configured parameters) and START_DLC(RQ) commands to the node operator facility (NOF). NOF, in turn, passes DEFINE_DLC(RQ) and START_DLC(RQ) signals to configuration services (CS), and CS creates the DLC manager. Then, the node operator can define a port by issuing DEFINE_PORT(RQ) (also containing customer-configured parameters) to NOF with NOF passing the associated signal to CS.

A node with adapters attached to multiple IP subnetworks may represent the multiple adapters as a single HPR/IP port. However, in that case, the node associates a single IP address with that port. RFC 1122 [9] requires that a node with multiple adapters be able to use the same source IP address on outgoing UDP packets regardless of the adapter used for transmission.

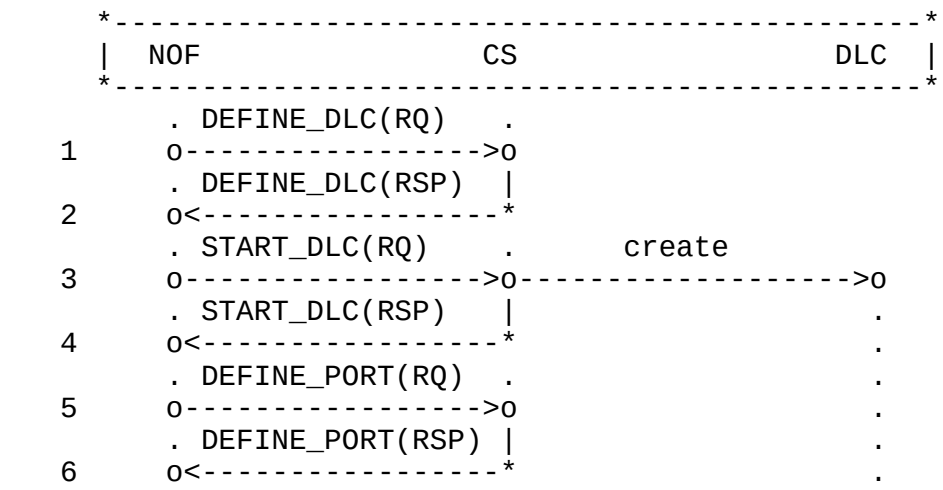


Figure 2. IP Port Activation

The following parameters are received in DEFINE_PORT(RQ):

- Port name
- DLC name
- Port type (if IP connection networks are supported, set to shared access transport facility [SATF]; otherwise, set to switched)
- Link station role (set to negotiable)
- Maximum receive BTU size (default is 1461 [1492 less an allowance for the IP, UDP, and LLC headers])
- Maximum send BTU size (default is 1461 [1492 less an allowance for the IP, UDP, and LLC headers])
- Link activation limits (total, inbound, and outbound)
- IPv4 supported (set to yes)
- The local IPv4 address (required if IPv4 is supported)
- IPv6 supported (set to no; may be set to yes in the future; see 2.9, "IPv4-to-IPv6 Migration" on page 35)
- The local IPv6 address (required if IPv6 is supported)
- Retry count for LDLC (default is 3)

- Retry timer period for LDLC (default is 15 seconds; a smaller value such as 10 seconds can be used for a campus network)

- LDLC liveness timer period (default is 10 seconds; see 2.3.1, "LDLC Liveness" on page 7)

- IP precedence (the setting of the 3-bit field within the Type of Service byte of the IP header for the LLC commands such as XID and for each of the APPN transmission priorities; the defaults are given in 2.6.1, "IP Prioritization" on page 28.)

2.4.1 Maximum BTU Sizes for HPR/IP

When IP datagrams are larger than the underlying physical links support, IP performs fragmentation. When HPR/IP links are established, the default maximum basic transmission unit (BTU) sizes are 1461 bytes, which corresponds to the typical IP maximum transmission unit (MTU) size of 1492 bytes supported by routers on token-ring networks. 1461 is 1492 less 20 bytes for the IP header, 8 bytes for the UDP header, and 3 bytes for the IEEE 802.2 LLC header. The IP header is larger than 20 bytes when optional fields are included; smaller maximum BTU sizes should be configured if optional IP header fields are used in the IP network. For IPv6, the default is reduced to 1441 bytes to allow for the typical IPv6 header size of 40 bytes. Smaller maximum BTU sizes (but not less than 768) should be used to avoid fragmentation when necessary. Larger BTU sizes should be used to improve performance when the customer’s IP network supports a sufficiently large IP MTU size. The maximum receive and send BTU sizes are passed to CS in DEFINE_PORT(RQ). These maximum BTU sizes can be overridden in DEFINE_CN_TG(RQ) or DEFINE_LS(RQ).

The Flags field in the IP header should be set to allow fragmentation. Some products will not be able to control the setting of the bit allowing fragmentation; in that case, fragmentation will most likely be allowed. Although fragmentation is slow and prevents prioritization based on UDP port numbers, it does allow connectivity across paths with small MTU sizes.

2.5 IP Transmission Groups (TGs)

2.5.1 Regular TGs

Regular HPR TGs may be established in IP networks using the native IP DLC architecture. Each of these TGs is composed of one or more HPR/IP links. Configuration services (CS) identifies the TG with the destination control point (CP) name and TG number; the destination CP

name may be configured or learned via XID, and the TG number, which may be configured, is negotiated via XID. For auto-activatable links, the destination CP name and TG number must be configured.

When multiple links (dynamic or defined) are established between a pair of IP ports (each associated with a single IP address), an incoming packet can be mapped to its associated link using the IP address pair and the service access point (SAP) address pair. If a node receives an activation XID for a defined link with an IP address pair and a SAP pair that are the same as for an active defined link, that node can assume that the link has failed and that the partner node is reactivating the link. In such a case as an optimization, the node receiving the XID can take down the active link and allow the link to be reestablished in the IP network. Because UDP packets can arrive out of order, implementation of this optimization requires the use of a timer to prevent a stray XID from deactivating an active link.

Support for multiple defined links between a pair of HPR/IP ports is optional. There is currently no value in defining multiple HPR/IP links between a pair of ports. In the future if HPR/IP support for the Resource ReSerVation Protocol (RSVP) [10] is defined, it may be advantageous to define such parallel links to segregate traffic by COS on RSVP "sessions." Using RSVP, HPR would be able to reserve bandwidth in IP networks. An HPR logical link would be mapped to an RSVP "session" that would likely be identified by either a specific application-provided UDP port number or a dynamically-assigned UDP port number.

When multiple defined HPR/IP links between ports are not supported, an incoming activation for a defined HPR/IP link may be rejected with sense data X’10160045’ if an active defined HPR/IP link already exists between the ports. If the SAP pair in the activation XID matches the SAP pair for the existing link, the optimization described above may be used instead.

If parallel defined HPR/IP links between ports are not supported, an incoming activation XID is mapped to the defined link station (if it exists) associated with the port on the adjacent node using the source IP address in the incoming activation XID. This source IP address should be the same as the destination IP address associated with the matching defined link station. (They may not be the same if the adjacent node has multiple IP addresses, and the configuration was not coordinated correctly.)

If parallel HPR/IP links between ports are supported, multiple defined link stations may be associated with the port on the adjacent node. In that case, predefined TG numbers (see "Partitioning the TG

Number Space" in Chapter 9 Configuration Services of [1]) may be used to map the XID to a specific link station. However, because the same TG characteristics may be used for all HPR/IP links between a given pair of ports, all the link stations associated with the port in the adjacent node should be equivalent; as a result, TG number negotiation using negotiable TG numbers may be used.

In the future, if multiple HPR/IP links with different characteristics are defined between a pair of ports using RSVP, defined link stations will need sufficient configured information to be matched with incoming XIDs. (Correct matching of an incoming XID to a defined link station allows CS to provide the correct TG characteristics to topology and routing services (TRS).) At that time CS will do the mapping based on both the IP address of the adjacent node and a predefined TG number.

The node initiating link activation knows which link it is activating. Some parameters sent in prenegotiation XID are defined in the regular link station configuration and not allowed to change in following negotiation-proceeding XIDs. To allow for forward migration to RSVP, when a regular TG is activated in an IP network, the node receiving the first XID (i.e., the node not initiating link activation) must also understand which defined link station is being activated before sending a prenegotiation XID in order to correctly set parameters that cannot change. For this reason, the node initiating link activation will indicate the TG number in prenegotiation XIDs by including a TG Descriptor (X'46') control vector containing a TG Identifier (X'80') subfield. Furthermore, the node receiving the first XID will force the node activating the link to send the first prenegotiation XID by responding to null XIDs with null XIDs. To prevent potential deadlocks, the node receiving the first XID has a limit (the LDLC retry count can be used) on the number of null XIDs it will send. Once this limit is reached, that node will send an XID with an XID Negotiation Error (X'22') control vector in response to a null XID; sense data X'0809003A' is included in the control vector to indicate unexpected null XID. If the node that received the first XID receives a prenegotiation XID without the TG Identifier subfield, it will send an XID with an XID Negotiation Error control vector to reject the link connection; sense data X'088C4680' is included in the control vector to indicate the subfield was missing.

For a regular TG, the TG parameters are provided by the node operator based on customer configuration in DEFINE_PORT(RQ) and DEFINE_LS(RQ). The following parameters are supplied in DEFINE_LS(RQ) for HPR/IP links:

- The destination IP host name (this parameter can usually be mapped to the destination IP address): If the link is not activated at node initialization, the IP host name should be mapped to an IP address, and the IP address should be stored with the link station definition. This is required to allow an incoming link activation to be matched with the link station definition. If the adjacent node activates the link with a different IP address (e.g., it could have multiple ports), it will not be possible to match the link activation with the link station definition, and the default parameters specified in the local port definition will be used.

- The destination IP version (set to version 4, support for version 6 may be required in the future; this parameter is only required if the address and version cannot be determined using the destination IP host name.)

- The destination IP address (in the format specified by the destination IP version; this parameter is only required if the address cannot be determined using the destination IP host name.)

- Source service access point address (SSAP) used for XID, TEST, DISC, and DM (default is X'04'; other values may be specified when multiple links between a pair of IP addresses are defined)

- Destination service access point address (DSAP) used for XID, TEST, DISC, and DM (default is X'04')

- Source service access point address (SSAP) used for HPR network layer packets (NLPs) (default is X'C8'; other values may be specified when multiple links between a pair of IP addresses are defined.)

- Maximum receive BTU size (default is 1461; this parameter is used to override the setting in DEFINE_PORT.)

- Maximum send BTU size (default is 1461; this parameter is used to override the setting in DEFINE_PORT.)

- IP precedence (the setting of the 3-bit field within the Type of Service byte of the IP header for LLC commands such as XID and for each of the APPN transmission priorities; the defaults are given in 2.6.1, "IP Prioritization" on page 28; this parameter is used to override the settings in DEFINE_PORT)

- Shareable with connection network traffic (default is yes for non-RSVP links)

- Retry count for LDLC (default is 3; this parameter is used to override the setting in DEFINE_PORT)
- Retry timer period for LDLC (default is 15 seconds; a smaller value such as 10 seconds can be used for a campus link; this parameter is used to override the setting in DEFINE_PORT)
- LDLC liveness timer period (default is 10 seconds; this parameter is to override the setting in DEFINE_PORT; see 2.3.1, "LDLC ness" on page 7)
- Auto-activation supported (default is no; may be set to yes when the local node has switched access to the IP network)
- Limited resource (default is to set in concert with auto-activation supported)
- Limited resource liveness timer (default is 45 sec.)
- Port name
- Adjacent CP name (optional)
- Local CP-CP sessions supported
- Defined TG number (optional)
- TG characteristics

The following figures show the activation and deactivation of regular TGs.

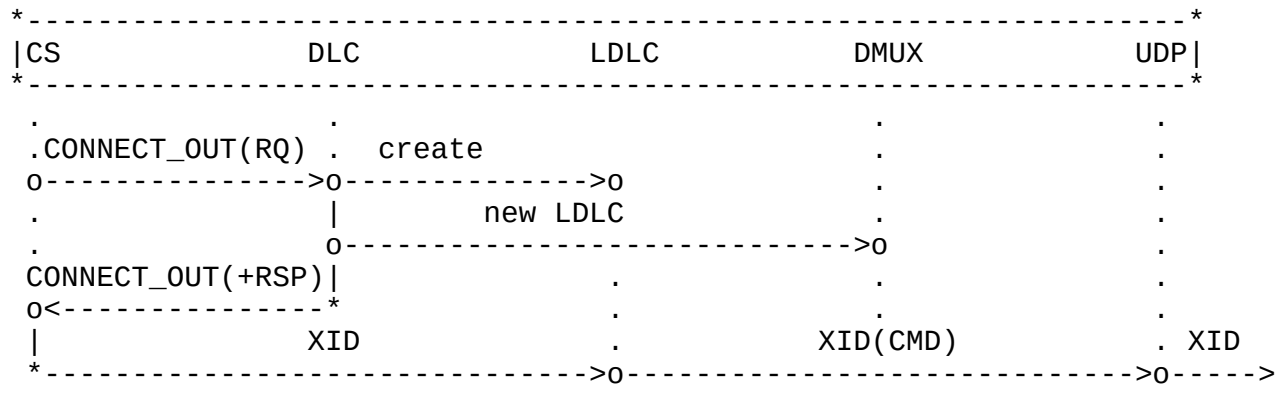


Figure 3. Regular TG Activation (outgoing)

In Figure 3 upon receiving START_LS(RQ) from NOF, CS starts the link activation process by sending CONNECT_OUT(RQ) to the DLC manager. The DLC manager creates an instance of LDLC for the link, informs the link demultiplexor, and sends CONNECT_OUT(+RSP) to CS. Then, CS starts the activation XID exchange.

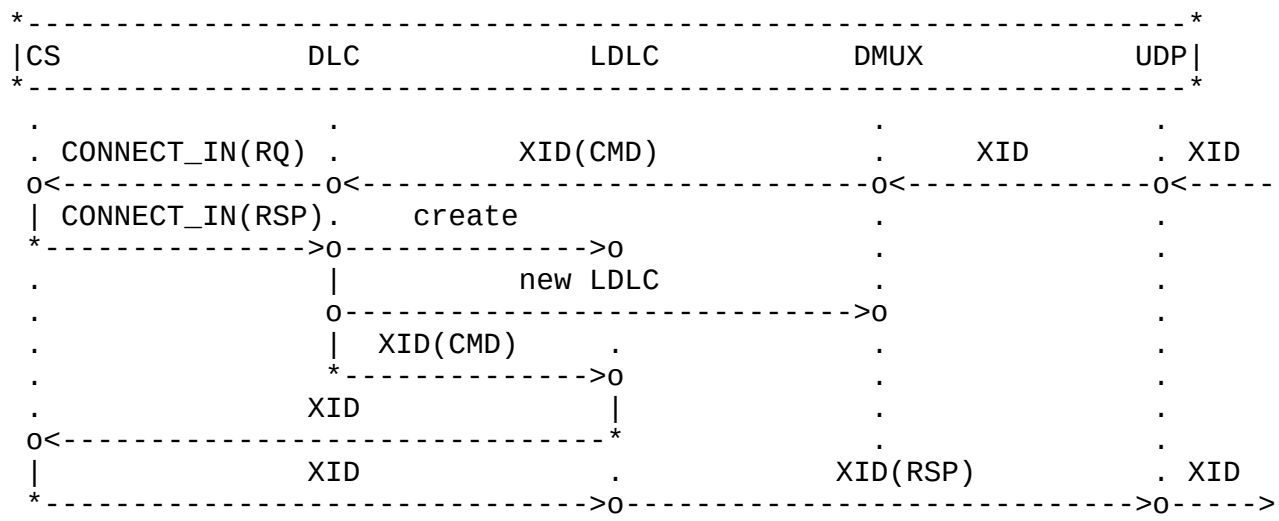


Figure 4. Regular TG Activation (incoming)

In Figure 4, when an XID is received for a new link, it is passed to the DLC manager. The DLC manager sends CONNECT_IN(RQ) to notify CS of the incoming link activation, and CS sends CONNECT_IN(+RSP) accepting the link activation. The DLC manager then creates a new instance of LDLC, informs the link demultiplexor, and forwards the XID to to CS via LDLC. CS then responds by sending an XID to the adjacent node.

The two following figures show normal TG deactivation (outgoing and incoming).

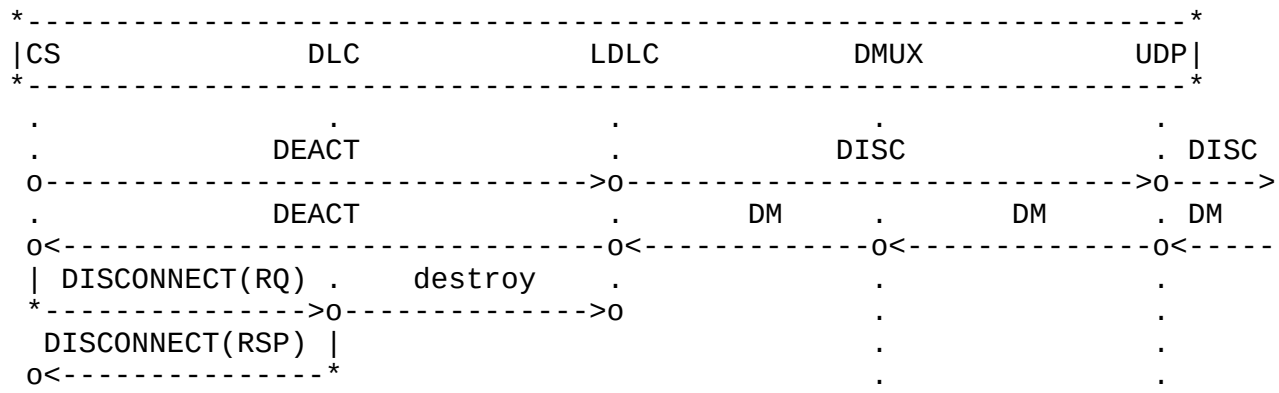


Figure 5. Regular TG Deactivation (outgoing)

In Figure 5 upon receiving STOP_LS(RQ) from NOF, CS sends DEACT to notify the partner node that the HPR link is being deactivated. When the response is received, CS sends DISCONNECT(RQ) to the DLC manager, and the DLC manager deactivates the instance of LDLC. Upon receiving DISCONNECT(RSP), CS sends STOP_LS(RSP) to NOF.

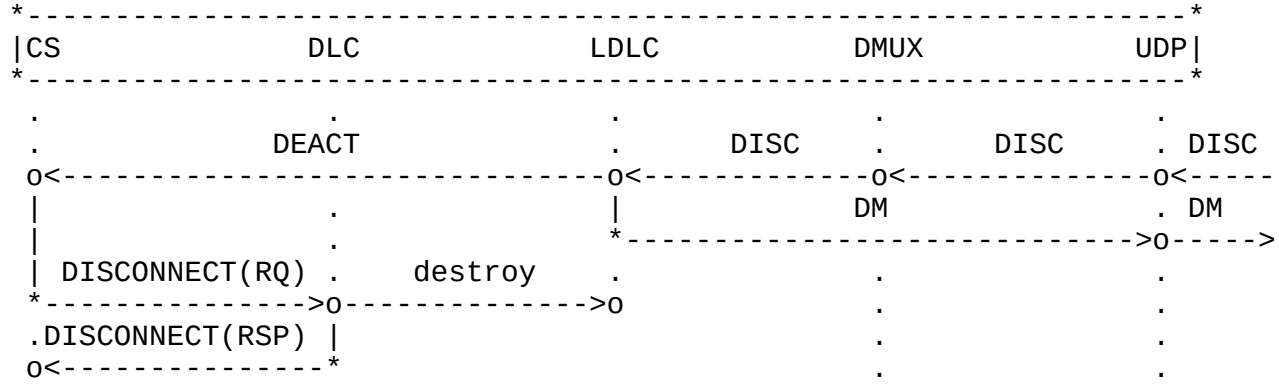


Figure 6. Regular TG Deactivation (incoming)

In Figure 6, when an adjacent node deactivates a TG, the local node receives a DISC. CS sends STOP_LS(IND) to NOF. Because IP is connectionless, the DLC manager is not aware that the link has been deactivated. For that reason, CS also needs to send DISCONNECT(RQ) to the DLC manager; the DLC manager deactivates the instance of LDLC.

2.5.1.1 Limited Resources and Auto-Activation

To reduce tariff charges, the APPN architecture supports the definition of switched links as limited resources. A limited-resource link is deactivated when there are no sessions traversing the link. Intermediate HPR nodes are not aware of sessions between logical units (referred to as LU-LU sessions) carried in crossing RTP connections; in HPR nodes, limited-resource TGs are deactivated when no traffic is detected for some period of time. Furthermore, APPN links may be defined as auto-activatable. Auto-activatable links are activated when a new session has been routed across the link.

An HPR node may have access to an IP network via a switched access link. In such environments, it may be advisable for customers to define regular HPR/IP links as limited resources and as being auto-activatable.

2.5.2 IP Connection Networks

Connection network support for IP networks (option set 2010), is described in this section.

APPN architecture defines single link TGs across the point-to-point lines connecting APPN nodes. The natural extension of this model would be to define a TG between each pair of nodes connected to a shared access transport facility (SATF) such as a LAN or IP network. However, the high cost of the system definition of such a mesh of TGs is prohibitive for a network of more than a few nodes. For that reason, the APPN connection network model was devised to reduce the system definition required to establish TGs between APPN nodes.

Other TGs may be defined through the SATF which are not part of the connection network. Such TGs (referred to as regular TGs in this document) are required for sessions between control points (referred to as CP-CP sessions) but may also be used for LU-LU sessions.

In the connection network model, a virtual routing node (VRN) is defined to represent the SATF. Each node attached to the SATF defines a single TG to the VRN rather than TGs to all other attached nodes.

Topology and routing services (TRS) specifies that a session is to be routed between two nodes across a connection network by including the connection network TGs between each of those nodes and the VRN in the Route Selection control vector (RSCV). When a network node has a TG to a VRN, the network topology information associated with that TG includes DLC signaling information required to establish connectivity to that node across the SATF. For an end node, the DLC signaling

information is returned as part of the normal directory services (DS) process. TRS includes the DLC signaling information for TGs across connection networks in RSCVs.

CS creates a dynamic link station when the next hop in the RSCV of an ACTIVATE_ROUTE signal received from session services (SS) is a connection network TG or when an adjacent node initiates link activation upon receiving such an ACTIVATE_ROUTE signal. Dynamic link stations are normally treated as limited resources, which means they are deactivated when no sessions are using them. CP-CP sessions are not supported on connections using dynamic link stations because CP-CP sessions normally need to be kept up continuously.

Establishment of a link across a connection network normally requires the use of CP-CP sessions to determine the destination IP address. Because CP-CP sessions must flow across regular TGs, the definition of a connection network does not eliminate the need to define regular TGs as well.

Normally, one connection network is defined on a LAN (i.e., one VRN is defined.) For an environment with several interconnected campus IP networks, a single wide-area connection network can be defined; in addition, separate connection networks can be defined between the nodes connected to each campus IP network.

2.5.2.1 Establishing IP Connection Networks

Once the port is defined, a connection network can be defined on the port. In order to support multiple TGs from a port to a VRN, the connection network is defined by the following process:

1. A connection network and its associated VRN are defined on the port. This is accomplished by the node operator issuing a DEFINE_CONNECTION_NETWORK(RQ) command to NOF and NOF passing a DEFINE_CN(RQ) signal to CS.

2. Each TG from the port to the VRN is defined by the node operator issuing DEFINE_CONNECTION_NETWORK_TG(RQ) to NOF and NOF passing DEFINE_CN_TG(RQ) to CS.

Prior to implementation of Resource ReSerVation Protocol (RSVP) support, only one connection network TG between a port and a VRN is required. In that case, product support for the DEFINE_CN_TG(RQ) signal is not required because a single set of port configuration parameters for each connection network is sufficient. If a NOF implementation does not support DEFINE_CN_TG(RQ), the parameters listed in the following section for DEFINE_CN_TG(RQ), are provided by DEFINE_CN(RQ) instead. Furthermore, the Connection Network TG

Numbers (X'81') subfield in the TG Descriptor (X'46') control vector on an activation XID is only required to support multiple connection network TGs to a VRN, and its use is optional.

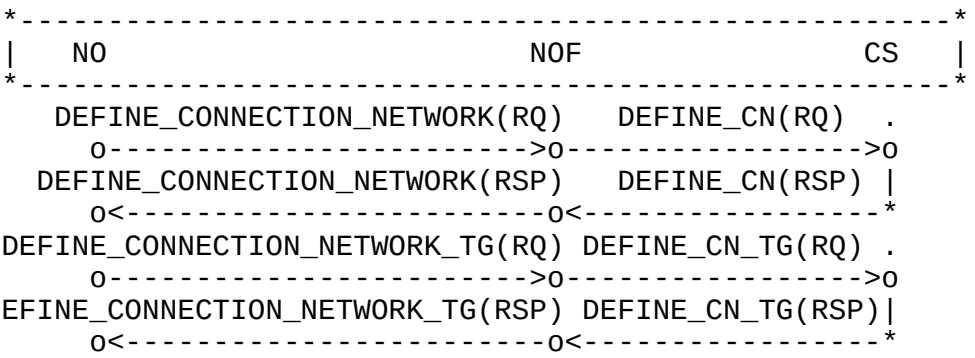


Figure 7. IP Connection Network Definition

An incoming dynamic link activation may be rejected with sense data X'10160046' if there is an existing dynamic link between the two ports over the same connection network (i.e., with the same VRN CP name). If a node receives an activation XID for a dynamic link with an IP address pair, a SAP pair, and a VRN CP name that are the same as for an active dynamic link, that node can assume that the link has failed and that the partner node is reactivating the link. In such a case as an optimization, the node receiving the XID can take down the active link and allow the link to be reestablished in the IP network. Because UDP packets can arrive out of order, implementation of this optimization requires the use of a timer to prevent a stray XID from deactivating an active link.

Once all the connection networks are defined, the node operator issues START_PORT(RQ), NOF passes the associated signal to CS, and CS passes ACTIVATE_PORT(RQ) to the DLC manager. Upon receiving the ACTIVATE_PORT(RSP) signal from the DLC manager, CS sends a TG_UPDATE signal to TRS for each defined connection network TG. Each signal notifies TRS that a TG to the VRN has been activated and includes TG vectors describing the TG. If the port fails or is deactivated, CS sends TG_UPDATE indicating the connection network TGs are no longer operational. Information about TGs between a network node and the VRN is maintained in the network topology database. Information about TGs between an end node and the VRN is maintained only in the local topology database. If TRS has no node entry in its topology database for the VRN, TRS dynamically creates such an entry. A VRN node entry will become part of the network topology database only if

a network node has defined a TG to the VRN; however, TRS is capable of selecting a direct path between two end nodes across a connection network without a VRN node entry.

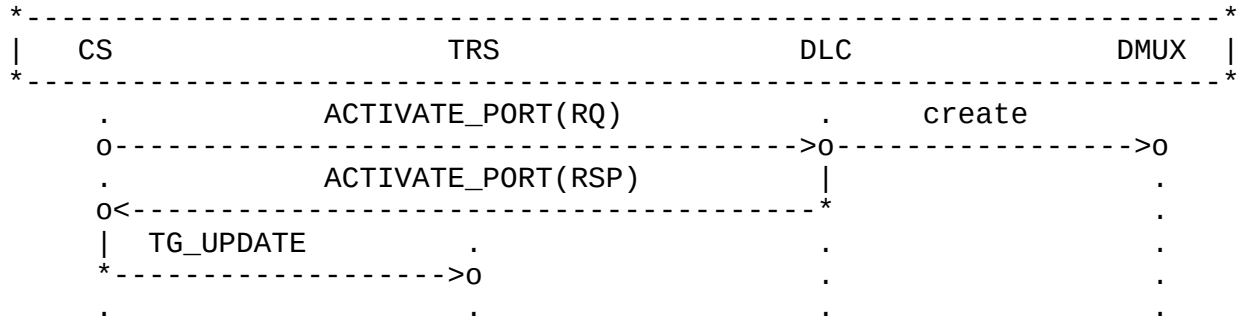


Figure 8. IP Connection Network Establishment

The TG vectors for IP connection network TGs include the following information:

- TG number
- VRN CP name
- TG characteristics used during route selection
  - Effective capacity
  - Cost per connect time
  - Cost per byte transmitted
  - Security
  - Propagation delay
  - User defined parameters
- Signaling information
  - IP version (indicates the format of the IP header including the IP address)
  - IP address
  - Link service access point address (LSAP) used for XID, TEST, DISC, and DM

2.5.2.2 IP Connection Network Parameters

For a connection network TG, the parameters are determined by CS using several inputs. Parameters that are particular to the local port, connection network, or TG are system defined and received in

DEFINE_PORT(RQ), DEFINE_CN(RQ), or DEFINE_CN_TG(RQ). Signaling information for the destination node including its IP address is received in the ACTIVATE_ROUTE request from SS.

The following configuration parameters are received in DEFINE_CN(RQ):

- Connection network name (CP name of the VRN)
- Limited resource liveness timer (default is 45 sec.)
- IP precedence (the setting of the 3-bit field within the Type of Service byte of the IP header for LLC commands such as XID and for each of the APPN transmission priorities; the defaults are given in 2.6.1, "IP Prioritization" on page 28; this parameter is used to override the settings in DEFINE_PORT)

The following configuration parameters are received in DEFINE_CN_TG(RQ):

- Port name
- Connection network name (CP name of the VRN)
- Connection network TG number (set to a value between 1 and 239)
- TG characteristics (see 2.6.3, "Default TG Characteristics" on page 30)
- Link service access point address (LSAP) used for XID, TEST, DISC, and DM (default is X'04')
- Link service access point address (LSAP) used for HPR network layer packets (default is X'C8')
- Limited resource (default is yes)
- Retry count for LDLC (default is 3; this parameter is used to override the setting in DEFINE_PORT)
- Retry timer period for LDLC (default is 15 sec.; a smaller value such as 10 seconds can be used for a campus connection network; this parameter is used to override the setting in DEFINE_PORT)
- LDLC liveness timer period (default is 10 seconds; this parameter is used to override the setting in DEFINE_PORT; see 2.3.1, "LDLC Liveness" on page 7)

- Shareable with other HPR traffic (default is yes for non-RSVP links)
- Maximum receive BTU size (default is 1461; this parameter is used to override the value in DEFINE_PORT(RQ).)
- Maximum send BTU size (default is 1461; this parameter is used to override the value in DEFINE_PORT(RQ).)

The following parameters are received in ACTIVATE_ROUTE for connection network TGs:

- The TG pair
- The destination IP version (if this version is not supported by the local node, the ACTIVATE_ROUTE_RSP reports the activation failure with sense data X'086B46A5'.)
- The destination IP address (in the format specified by the destination IP version)
- Destination service access point address (DSAP) used for XID, TEST, DISC, and DM

2.5.2.3 Sharing of TGs

Connection network traffic is multiplexed onto a regular defined IP TG (usually used for CP-CP session traffic) in order to reduce the control block storage. No XIDs flow to establish a new TG on the IP network, and no new LLC is created. When a regular TG is shared, incoming traffic is demultiplexed using the normal means. If the regular TG is deactivated, a path switch is required for the HPR connection network traffic sharing the TG.

Multiplexing is possible if the following conditions hold:

1. Both the regular TG and the connection network TG to the VRN are defined as shareable between HPR traffic streams.
2. The destination IP address is the same.
3. The regular TG is established first. (Because links established for connection network traffic do not support CP-CP sessions, there is little value in allowing a regular TG to share such a link.)

The destination node is notified via XID when a TG can be shared between HPR data streams. At either end, upon receiving

ACTIVATE_ROUTE requesting a shared TG for connection network traffic, CS checks its TGs for one meeting the required specifications before initiating a new link. First, CS looks for a link established for the TG pair; if there is no such link, CS determines if there is a regular TG that can be shared and, if multiple such TGs exist, which TG to choose. As a result, RTP connections routed over the same TG pair may actually use different links, and RTP connections routed over different TG pairs may use the same link.

2.5.2.4 Minimizing RSCV Length

The maximum length of a Route Selection (X'2B') control vector (RSCV) is 255 bytes. Use of connection networks significantly increases the size of the RSCV contents required to describe a "hop" across an SATF. First, because two connection network TGs are used to specify an SATF hop, two TG Descriptor (X'46') control vectors are required. Furthermore, inclusion of DLC signaling information within the TG Descriptor control vectors increases the length of these control vectors. As a result, the total number of hops that can be specified in RSCVs traversing connection networks is reduced.

To avoid unnecessarily limiting the number of hops, a primary goal in designing the formats for IP signaling information is to minimize their size. Additional techniques are also used to reduce the effect of the RSCV length limitation.

For an IP connection network, DLC signaling information is required only for the second TG (i.e., from the VRN to the destination node); the signaling information for the first TG is locally defined at the origin node. For this reason, the topology database does not include DLC signaling information for the entry describing a connection network TG from a network node to a VRN. The DLC signaling information is included in the allied entry for the TG in the opposite direction. This mechanism cannot be used for a connection network TG between a VRN and an end node. However, a node implementing IP connection networks does not include IP signaling information for the first connection network TG when constructing an RSCV.

In an environment where APPN network nodes are used to route between legacy LANs and wide-area IP networks, it is recommended that customers not define connection network TGs between these network nodes and VRNs representing legacy LANs. Typically, defined links are required between end nodes on the legacy LANs and such network nodes which also act as network node servers for the end nodes. These defined links can be used for user traffic as well as control traffic. This technique will reduce the number of connection network hops in RSCVs between end nodes on different legacy LANs.

Lastly, for environments where RSCVs are still not able to include enough hops, extended border nodes (EBNs) can be used to partition the network. In this case, the EBNs will also provide piecewise subnet route calculation and RSCV swapping. Thus, the entire route does not need to be described in a single RSCV with its length limitation.

2.5.3 XID Changes

Packets transmitted over IP networks are lost or arrive out of order more often than packets transmitted over other "link" technologies. As a result, the following problem with the XID3 negotiation protocol was exposed:

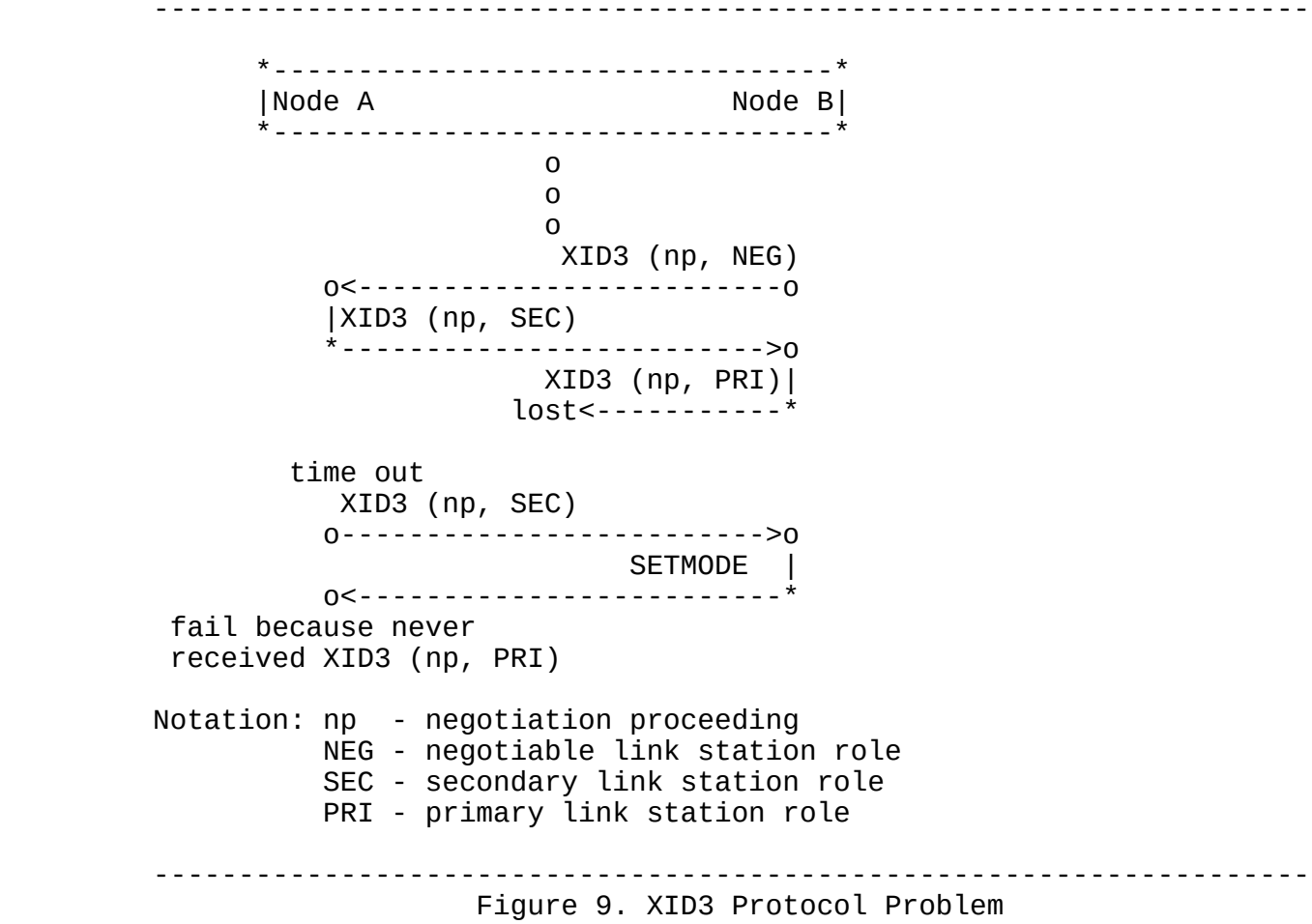


Figure 9. XID3 Protocol Problem

In the above sequence, the XID3(np, PRI), which is a link-level response to the received XID3(np, SEC), is lost. Node A times out and resends the XID3(np, SEC) as a link-level command. When Node B

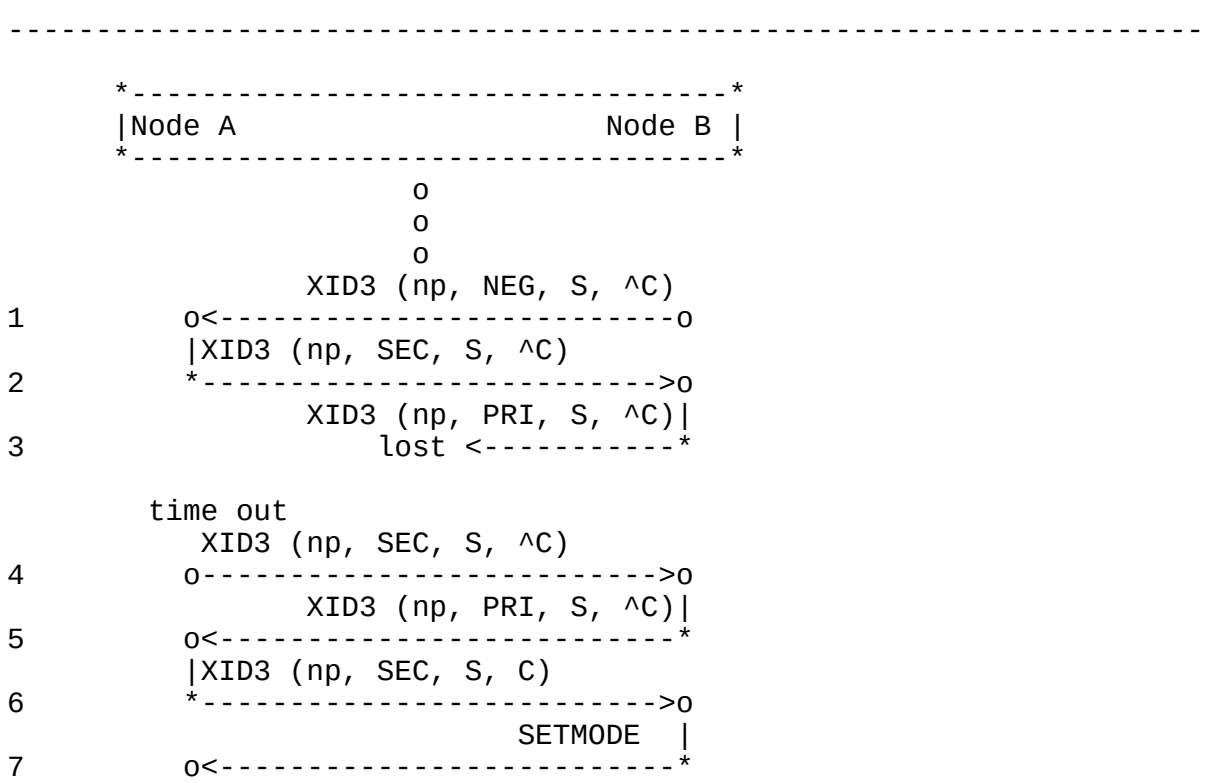
receives this command, it thinks that the XID3(np, PRI) was successfully received by Node A and that the activation XID exchange is complete. As a result, Node B sends SETMODE (SNRM, SABME, or XID_DONE_RQ, depending upon the link type). When Node A receives SETMODE, it fails the link activation because it has not received an XID3(np, PRI) from Node B confirming that Node B does indeed agree to be the primary. Moreover, there are similar problems with incomplete TG number negotiation.

To solve the problems with incomplete role and TG number negotiation, two new indicators are defined in XID3. The problems are solved only if both link stations support these new indicators:

- Negotiation Complete Supported indicator (byte 12 bit 0) -- this 1-bit field indicates whether the Negotiation Complete indicator is supported. This field is meaningful when the XID exchange state is negotiation proceeding; otherwise, it is reserved. A value of 0 means the Negotiation Complete indicator is not supported; a value of 1 means the indicator is supported.

- Negotiation Complete indicator (byte 12 bit 1) -- this 1-bit field is meaningful only when the XID exchange state is negotiation proceeding, the XID3 is sent by the secondary link station, and the Negotiation Complete Supported indicator is set to 1; otherwise, this field is reserved. This field is set to 1 by a secondary link station that supports enhanced XID negotiation when it considers the activation XID negotiation to be complete for both link station role and TG number (i.e., it is ready to receive a SETMODE command from the primary link station.)

When a primary link station that supports enhanced XID negotiation receives an XID3(np) with both the Negotiation Complete Supported indicator and the Negotiation Complete indicator set to 1, the primary link station will know that it can safely send SETMODE if it also considers the XID negotiation to be complete. The new indicators are used as shown in the following sequence when both the primary and secondary link stations support enhanced XID negotiation.



^S indicates that byte 12 bit 0 is set to 0.
S indicates that byte 12 bit 0 is set to 1.
^C indicates that byte 12 bit 1 is set to 0.
C indicates that byte 12 bit 1 is set to 1.

Figure 10. Enhanced XID Negotiation

When Node B receives the XID in flow 4, it realizes that the Node A does not consider XID negotiation to be complete; as a result, it resends its current XID information in flow 5. When Node A receives this XID, it responds in flow 6 with an XID that indicates XID negotiation is complete. At this point, Node B, acting as the primary link station, sends SETMODE, and the link is activated successfully.

Migration cases with only one link station supporting enhanced XID negotiation are shown in the two following sequences. In the next sequence, only Node A (acting as the secondary link station) supports the new function.

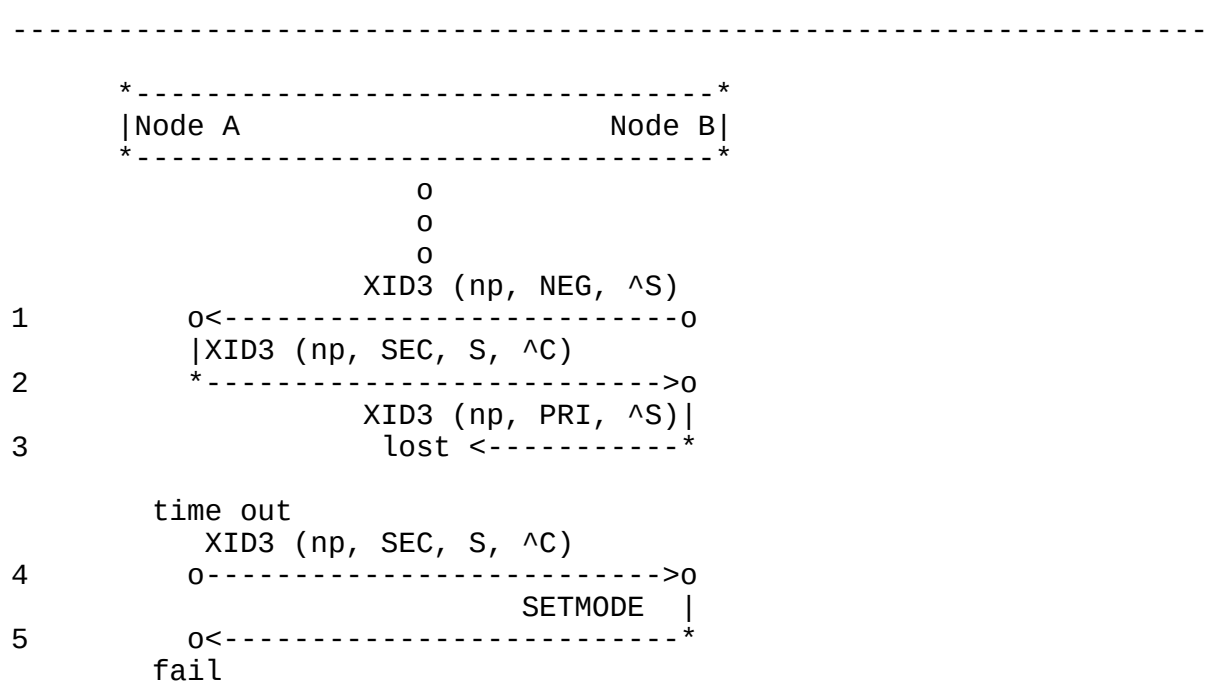


Figure 11. First Migration Case

The XID negotiation fails because Node B does not understand the new indicators and responds to flow 4 with SETMODE.

In the next sequence, Node B supports the new indicators but Node A does not.

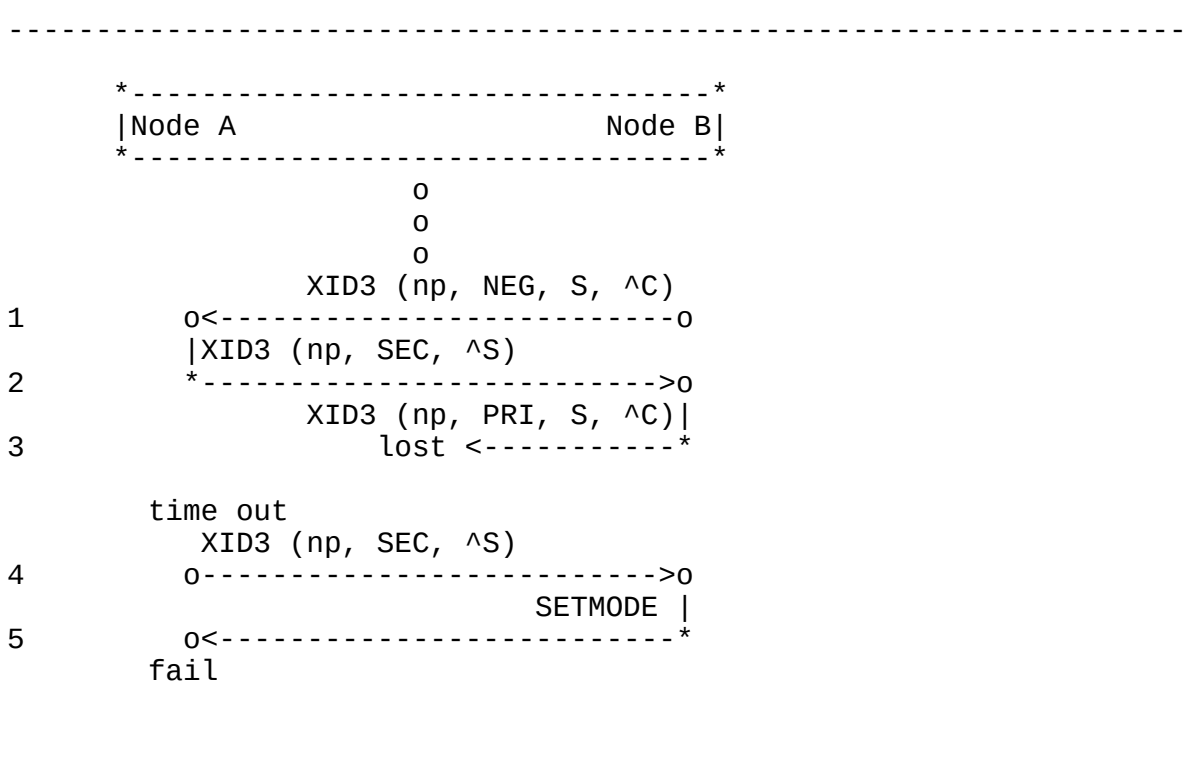


Figure 12. Second Migration Case

The XID negotiation fails because Nobe A does not understand the new indicators and thus cannot indicate that it thinks XID negotiation is not complete in flow 4. Node B understands that the secondary link station (node A) does not support the new indicators and respond with SETMODE in flow 5.

Products that support HPR/IP links are required to support enhanced XID negotiation. Moreover, it is recommended that products implementing this solution for HPR/IP links also support it for other link types.

2.5.4 Unsuccessful IP Link Activation

Link activation may fail for several different reasons. When link activation over a connection network or of an auto-activatable link is attempted upon receiving ACTIVATE_ROUTE from SS, activation failure is reported with ACTIVATE_ROUTE_RSP containing sense data explaining the cause of failure. Likewise, when activation fails for other regular defined links, the failure is reported with START_LS(RSP) containing sense data.

As is normal for session activation failures, the sense data is also sent to the node that initiated the session. At the APPN-to-HPR boundary, a -RSP(BIND) or an UNBIND with an Extended Sense Data control vector is generated and returned to the primary logical unit (PLU).

At an intermediate HPR node, link activation failure can be reported with sense data X'08010000' or X'80020000'. At a node with route-selection responsibility, such failure can be reported with sense data X'80140001'.

The following table contains the sense data for the various causes of link activation failure:

Table 1 (Page 1 of 2). Native IP DLC Link Activation Failure Sense Data

ERROR DESCRIPTION	SENSE DATA
The link specified in the RSCV is not available.	X'08010000'
The limit for null XID responses by a called node was reached.	X'0809003A'
A BIND was received over a subarea link, but the next hop is over a port that supports only HPR links. The receiver does not support this configuration.	X'08400002'
The contents of the DLC Signaling Type (X'91') subfield of the TG Descriptor (X'46') control vector contained in the RSCV were invalid.	X'086B4691'
The contents of the IP Address and Link Service Access Point Address (X'A5') subfield of the TG Descriptor (X'46') control vector contained in the RSCV were invalid.	X'086B46A5'
No DLC Signaling Type (X'91') subfield was found in the TG Descriptor (X'46') control vector contained in the RSCV.	X'086D4691'
No IP Address and Link Service Access Point Address (X'A5') subfield was found in the TG Descriptor (X'46') control vector contained in the RSCV.	X'086D46A5'
Multiple sets of DLC signaling information were found in the TG Descriptor (X'46') control vector contained in the RSCV. IP supports only one set of DLC signaling information.	X'08770019'
Link Definition Error: A link is defined as not supporting HPR, but the port only supports HPR links.	X'08770026'
A called node found no TG Identifier (X'80') subfield within a TG Descriptor (X'46') control vector in a prenegotiation XID for a defined link in an IP network.	X'088C4680'

Table 1 (Page 2 of 2). Native IP DLC Link Activation Failure Sense Data	
The XID3 received from the adjacent node does not contain an HPR Capabilities (X'61') control vector. The IP port supports only HPR links.	X'10160031'
The RTP Supported indicator is set to 0 in the HPR Capabilities (X'61') control vector of the XID3 received from the adjacent node. The IP port supports only links to nodes that support RTP.	X'10160032'
The Control Flows over RTP Supported indicator is set to 0 in the HPR Capabilities (X'61') control vector of the XID3 received from the adjacent node. The IP port supports only links to nodes that support control flows over RTP.	X'10160033'
The LDLC Supported indicator is set to 0 in the HPR Capabilities (X'61') control vector of the XID3 received from the adjacent node. The IP port supports only links to nodes that support LDLC.	X'10160034'
The HPR Capabilities (X'61') control vector received in XID3 does not include an IEEE 802.2 LLC (X'80') HPR Capabilities subfield. The subfield is required on an IP link.	X'10160044'
Multiple defined links between a pair of switched ports is not supported by the local node. A link activation request was received for a defined link, but there is an active defined link between the paired switched ports.	X'10160045'
Multiple dynamic links across a connection network between a pair of switched ports is not supported by the local node. A link activation request was received for a dynamic link, but there is an active dynamic link between the paired switched ports across the same connection network.	X'10160046'
Link failure	X'80020000'
Route selection services has determined that no path to the destination node exists for the specified COS.	X'80140001'

2.6 IP Throughput Characteristics

2.6.1 IP Prioritization

Typically, IP routers process packets on a first-come-first-served basis; i.e., no packets are given transmission priority. However, some IP routers prioritize packets based on IP precedence (the 3-bit field within the Type of Service byte of the IP header) or UDP port numbers. (With the current plans for IP security, the UDP port numbers are encrypted; as a result, IP routers would not be able to prioritize encrypted traffic based on the UDP port numbers.) HPR will be able to exploit routers that provide priority function.

The 5 UDP port numbers, 12000-12004 (decimal), have been assigned by the Internet Assigned Number Authority (IANA). Four of these port numbers are used for ANR-routed network layer packets (NLPs) and correspond to the APPN transmission priorities (network, 12001; high, 12002; medium, 12003; and low, 12004), and one port number (12000) is used for a set of LLC commands (i.e., XID, TEST, DISC, and DM) and function-routed NLPs (i.e., XID_DONE_RQ and XID_DONE_RSP). These port numbers are used for "listening" and are also used in the destination port number field of the UDP header of transmitted packets. The source port number field of the UDP header can be set either to one of these port numbers or to an ephemeral port number.

The IP precedence for each transmission priority and for the set of LLC commands (including function-routed NLPs) are configurable. The implicit assumption is that the precedence value is associated with priority queueing and not with bandwidth allocation; however, bandwidth allocation policies can be administered by matching on the precedence field. The default mapping to IP precedence is shown in the following table:

Table 2. Default IP Precedence Settings	
PRIORITY	PRECEDENCE
LLC commands and function-routed NLPs	110
Network	110
High	100
Medium	010
Low	001

As an example, with this default mapping, telnet, interactive ftp, and business-use web traffic could be mapped to a precedence value of 011, and batch ftp could be mapped to a value of 000.

These settings were devised based on the AIW's understanding of the intended use of IP precedence. The use of IP precedence will be modified appropriately if the IETF standardizes its use differently. The other fields in the IP TOS byte are not used and should be set to 0.

For outgoing ANR-routed NLPs, the destination (and optionally the source) UDP port numbers and IP precedence are set based on the transmission priority specified in the HPR network header.

It is expected that the native IP DLC architecture described in this document will be used primarily for private campus or wide-area intranets where the customer will be able to configure the routers to honor the transmission priority associated with the UDP port numbers or IP precedence. The architecture can be used to route HPR traffic in the Internet; however, in that environment, routers do not currently provide the priority function, and customers may find the performance unacceptable.

In the future, a form of bandwidth reservation may be possible in IP networks using the Resource ReSerVation Protocol (RSVP), or the differentiated services currently being studied by the Integrated Services working group of the IETF. Bandwidth could be reserved for an HPR/IP link thus insulating the HPR traffic from congestion associated with the traffic of other protocols.

2.6.2 APPN Transmission Priority and COS

APPN transmission priority and class of service (COS) allow APPN TGs to be highly utilized with batch traffic without impacting the performance of response-time sensitive interactive traffic. Furthermore, scheduling algorithms guarantee that lower-priority traffic is not completely blocked. The result is predictable performance.

When a session is initiated across an APPN network, the session's mode is mapped into a COS and transmission priority. For each COS, APPN has a COS table that is used in the route selection process to select the most appropriate TGs (based on their TG characteristics) for the session to traverse. The TG characteristics and COS tables are defined such that APPN topology and routing services (TRS) will select the appropriate TG for the traffic of each COS.

2.6.3 Default TG Characteristics

In Chapter 7 (TRS) of [1], there is a set of SNA-defined TG default profiles. When a TG (connection network or regular) is defined as being of a particular technology (e.g., ethernet or X.25) without specification of the TG's characteristics, parameters from the technology's default profile are used in the TG's topology entry. The customer is free to override these values via configuration. Some technologies have multiple profiles (e.g., ISDN has both a profile for switched and nonswitched.) Two default profiles are required for IP TGs. This many are needed because there are both campus and wide-area IP networks. As a result for each HPR/IP TG, a customer should specify, at minimum, campus or wide area. HPR/IP TGs traversing the Internet should be specified as wide-area links. If no specification is made, a campus network is assumed.

The 2 IP profiles are as follows:

Table 3. IP Default TG Characteristics

	Cost per connect time	Cost per byte	Security	Propagation delay	Effective capacity
Campus	0	0	X'01'	X'71'	X'75'
Wide area	0	0	X'20'	X'91'	X'43'

Typically, a TG is either considered to be "free" if it is owned or leased or "costly" if it is a switched carrier facility. Free TGs have 0 for both cost parameters, and costly TGs have 128 for both parameters. For campus IP networks, the default for both cost parameters is 0.

It is less clear what the defaults should be for wide area. Because a router normally has leased access to an IP network, the defaults for both costs are also 0. This assumes the IP network is not tariffed. However, if the IP network is tariffed, then the customer should set the cost per byte to 0 or 128 depending on whether the tariff contains a component based on quantity of data transmitted, and the customer should set the cost per connect time to 0 or 128 based on whether there is a tariff component based on connect time. Furthermore, for switched access to the IP network, the customer settings for both costs should also reflect the tariff associated with the switched access link.

Only architected values (see "Security" in [1]) may be used for a TG's security parameter. The default security value is X'01' (lowest) for campus and X'20' (public switched network; secure in the sense that there is no predetermined route the traffic will take) for wide-area IP networks. The network administrator may override the default value but should, in that case, ensure that an appropriate level of security exists.

For wide area, the value X'91' (packet switched) is the default for propagation delay; this is consistent with other wide-area facilities and indicates that IP packets will experience both terrestrial propagation delay and queueing delay in intermediate routers. This value is suitable for both the Internet and wide-area intranets; however, the customer could use different values to favor intranets over the Internet during route selection. The value X'99' (long) may be appropriate for some international links across the Internet. For campus, the default is X'71' (terrestrial); this setting essentially equates the queueing delay in IP networks with terrestrial propagation delay.

For wide area, X'43' (56 kbs) is shown as the default effective capacity; this is at the low-end of typical speeds for wide-area IP links. For campus, X'75' (4 Mbs) is the default; this is at the low-end of typical speeds for campus IP links. However, customers should set the effective capacity for both campus and wide area IP links based on the actual physical speed of the access link to the IP network; for regular links, if both the source and destination access speeds are known, customers should set the effective capacity based on the minimum of these two link speeds. If there are multiple access links, the capacity setting should be based on the physical

speed of the access link that is expected to be used for the link.

For the encoding technique for effective capacity in the topology database, see "Effective Capacity" in Chapter 7, Topology and Routing Services of [1]. The table in that section can be extended as follows for higher speeds:

Table 4. Calculated Effective Capacity Representations	
Link Speed (Approx.)	Effective Capacity
25M	X'8A'
45M	X'91'
100M	X'9A'
155M	X'A0'
467M	X'AC'
622M	X'B0'
1G	X'B5'
1.9G	X'BC'

2.6.4 SNA-Defined COS Tables

SNA-defined batch and interactive COS tables are provided in [1]. These tables are enhanced in [2] (see section 18.7.2) for the following reasons:

- To ensure that the tables assign reasonable weights to ATM TGs relative to each other and other technologies based on cost, speed, and delay
- To facilitate use of other new higher-speed facilities - This goal is met by providing several speed groupings above 10 Mbps. To keep the tables from growing beyond 12 rows, low-speed groupings are merged.

Products implementing the native IP DLC should use the new COS tables. Although the effective capacity values in the old tables are sufficient for typical IP speeds, the new tables are valuable because higher-speed links can be used for IP networks.

2.6.5 Route Setup over HPR/IP links

The Resequence ("REFIFO") indicator is set in Route Setup request and reply when the RTP path uses a multi-link TG because packets may not be received in the order sent. The Resequence indicator is also set when the RTP path includes an HPR/IP link as packets sent over an IP network may arrive out of order.

Adaptive rate-based congestion control (ARB) is an HPR Rapid Transport Protocol (RTP) function that controls the data transmission rate over RTP connections. ARB also provides fairness between the RTP traffic streams sharing a link. For ARB to perform these functions in the IP environment, it is necessary to coordinate the ARB parameters with the IP TG characteristics. This is done for IP links in a similar manner to that done for other link types.

2.6.6 Access Link Queueing

Typically, nodes implementing the native IP DLC have an access link to a network of IP routers. These IP routers may be providing prioritization based on UDP port numbers or IP precedence. A node implementing the native IP DLC can be either an IP host or an IP router; in both cases, such nodes should also honor the priorities associated with either the UDP port numbers or the IP precedence when transmitting HPR data over the access link to the IP network.

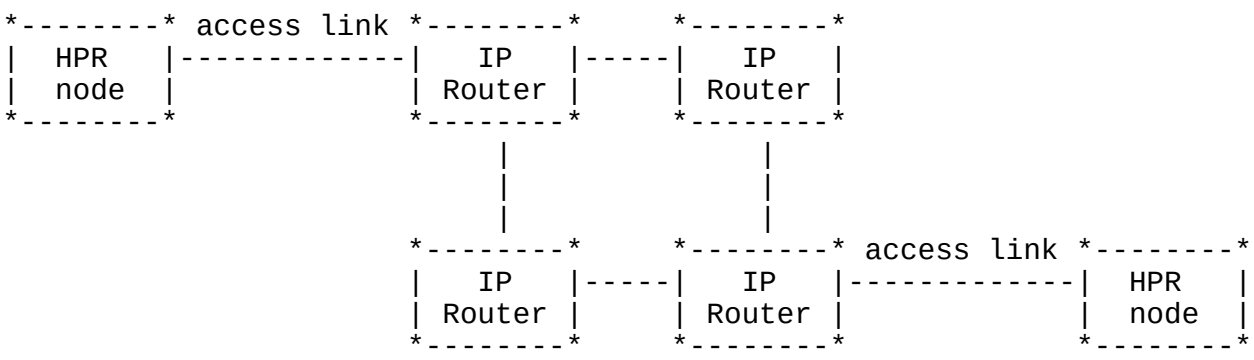


Figure 13. Access Links

Otherwise, the priority function in the router network will be negated with the result being HPR interactive traffic delayed by either HPR batch traffic or the traffic of other higher-layer protocols at the access link queues.

2.7 Port Link Activation Limits

Three parameters are provided by NOF to CS on DEFINE_PORT(RQ) to define the link activation limits for a port: total limit, inbound limit, and outbound limit. The total limit is the desired maximum number of active link stations allowed on the port for both regular TGs and connection network TGs. The inbound limit is the desired number of link stations reserved for connections initiated by adjacent nodes; the purpose of this field is to insure that a minimum number of link stations may be activated by adjacent nodes. The outbound limit is the desired number of link stations reserved for connections initiated by the local node. The sum of the inbound and outbound limits must be less than or equal to the total limit. If the sum is less than the total limit, the difference is the number of link stations that can be activated on a demand basis as either inbound or outbound. These limits should be based on the actual adapter capability and the node's resources (e.g., control blocks).

A connection network TG will be reported to topology as quiescing when its port's total limit threshold is reached; likewise, an inactive auto-activatable regular TG is reported as nonoperational. When the number of active link stations drops far enough below the threshold (e.g., so that at least 20 percent of the original link activation limit has been recovered), connection network TGs are reported as not quiescing, and auto-activatable TGs are reported as operational.

2.8 Network Management

APPN and HPR management information is defined by the APPN MIB (RFC 2155 [11]) and the HPR MIB (RFC 2238 [13]). In addition, the SNANAU working group of the IETF plans to define an HPR-IP-MIB that will provide HPR/IP-specific management information. In particular, this MIB will provide a mapping of APPN traffic types to IP Type of Service Precedence values, as well as a count of UDP packets sent for each traffic type.

There are also rules that must be specified concerning the values an HPR/IP implementation returns for objects in the APPN MIB:

- Several objects in the APPN MIB have the syntax IANAifType. The value 126, defined as "IP (for APPN HPR in IP networks)" should be returned by the following three objects when they identify an HPR/IP link:
  - appnPortDlcType
  - appnLsDlcType
  - appnLsStatusDlcType

- Link-level addresses are reported in the following objects:

  - appnPortDlcLocalAddr
  - appnLsLocalAddr
  - appnLsRemoteAddr
  - appnLsStatusLocalAddr
  - appnLsStatusRemoteAddr

  All of these objects should return ASCII character strings that represent IP addresses in the usual dotted-decimal format. (At this point it's not clear what the "usual...format" will be for IPv6 addresses, but whatever it turns out to be, that is what these objects will return when an HPR/IP link traverses an IP network.)

- The following two objects return Object Identifiers that tie table entries in the APPN MIB to entries in lower-layer MIBs:

  - appnPortSpecific
  - appnLsSpecific

  Both of these objects should return the same value: a RowPointer to the ifEntry in the agent's ifTable for the physical interface associated with the local IP address for the port. If the agent implements the IP-MIB (RFC 2011 [12]), this association between the IP address and the physical interface will be represented in the ipNetToMediaTable.

2.9 IPv4-to-IPv6 Migration

The native IP DLC is architected to use IP version 4 (IPv4). However, support for IP version 6 (IPv6) may be required in the future.

IP routers and hosts can interoperate only if both ends use the same version of the IP protocol. However, most IPv6 implementations (routers and hosts) will actually have dual IPv4/IPv6 stacks. IPv4 and IPv6 traffic can share transmission facilities provided that the router/host at each end has a dual stack. IPv4 and IPv6 traffic will coexist on the same infrastructure in most areas. The version number in the IP header is used to map incoming packets to either the IPv4 or IPv6 stack. A dual-stack host which wishes to talk to an IPv4 host will use IPv4.

Hosts which have an IPv4 address can use it as an IPv6 address using a special IPv6 address prefix (i.e., it is an embedded IPv4 address). This mapping was provided mainly for "legacy" application compatibility purposes as such applications don't have the socket

structures needed to store full IPv6 addresses. Two IPv6 hosts may communicate using IPv6 with embedded-IPv4 addresses.

Both IPv4 and IPv6 addresses can be stored by the domain name service (DNS). When an application queries DNS, it asks for IPv4 addresses, IPv6 addresses, or both. So, it's the application that decides which stack to use based on which addresses it asks for.

Migration for HPR/IP ports will work as follows:

An HPR/IP port is configured to support IPv4, IPv6, or both. If IPv4 is supported, a local IPv4 address is defined; if IPv6 is supported, a local IPv6 address (which can be an embedded IPv4 address) is defined. If both IPv4 and IPv6 are supported, both a local IPv4 address and a local IPv6 address are defined.

Defined links will work as follows: If the local node supports IPv4 only, a destination IPv4 address may be defined, or an IP host name may be defined in which case DNS will be queried for an IPv4 address. If the local node supports IPv6 only, a destination IPv6 address may be defined, or an IP host name may be defined in which case DNS will be queried for an IPv6 address. If both IPv4 and IPv6 are supported, a destination IPv4 address may be defined, a destination IPv6 address may be defined, or an IP host name may be defined in which case DNS will be queried for both IPv4 and IPv6 addresses; if provided by DNS, an IPv6 address can be used, and an IPv4 address can be used otherwise.

Separate IPv4 and IPv6 connection networks can be defined. If the local node supports IPv4, it can define a connection network TG to the IPv4 VRN. If the local node supports IPv6, it can define a TG to the IPv6 VRN. If both are supported, TGs can be defined to both VRNs. Therefore, the signaling information received in RSCVs will be compatible with the local node's capabilities unless a configuration error has occurred.

3.0 References

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[10] Braden, R., Zhang, L., Berson, S., Herzog, S., and S. Jamin, "Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification", RFC 2205, September 1997.

[11] Clouston, B., and B. Moore, "Definitions of Managed Objects for APPN using SMIv2", RFC 2155, June 1997.

[12] McCloghrie, K., "SNMPv2 Management Information Base for the Internet Protocol using SMIv2", RFC 2011, November 1996.

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4.0 Security Considerations

For HPR, the IP network appears to be a link. For that reason, the SNA session-level security functions (user authentication, LU authentication, session encryption, etc.) are still available for use. In addition, as HPR traffic flows as UDP datagrams through the IP network, IPsec can be used to provide network-layer security inside the IP network.

There are firewall considerations when supporting HPR traffic using the native IP DLC. First, the firewall filters can be set to allow the HPR traffic to pass. Traffic can be restricted based on the source and destination IP addresses and the destination port number;

the source port number is not relevant. That is, the firewall should accept traffic with the IP addresses of the HPR/IP nodes and with destination port numbers in the range 12000 to 12004. Second, the possibility exists for an attack using forged UDP datagrams; such attacks could cause the RTP connection to fail or even introduce false data on a session. In environments where such attacks are expected, the use of network-layer security is recommended.

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6.0 Appendix - Packet Format

6.1 HPR Use of IP Formats

6.1.1 IP Format for LLC Commands and Responses
The formats described here are used for the following LLC commands and responses: XID command and response, TEST command and response, DISC command, and DM response.

IP Format for LLC Commands and Responses		
Byte	Bit	Content
0-p		IP header (see note 1)
p+1-p+8		UDP header (see note 2)
p+9-p+11		IEEE 802.2 LLC header (see note 3)
p+9		DSAP: same as for the base APPN (i.e., X'04' or an installation-defined value)
p+10		SSAP: same as for the base APPN (i.e., X'04' or an installation-defined value)
p+11		Control: set as appropriate
p+12-n		Remainder of PDU: XID3 or TEST information field, or null for DISC command and DM response

		Note 1: Rules for encoding the IP header can be found in RFC 791.
		Note 2: Rules for encoding the UDP header can be found in RFC 768.

IP Format for LLC Commands and Responses		
Byte	Bit	Content

		Note 3: Rules for encoding the IEEE 802.2 LLC header can be found in ISO/IEC 8802-2:1994 (ANSI/IEEE Std 802.2, 1994 Edition), Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 2: Logical Link Control.

6.1.2 IP Format for NLPs in UI Frames

This format is used for either LDLC specific messages or HPR session and control traffic.

IP Format for NLPs in UI Frames		
Byte	Bit	Content
0-p		IP header (see note 1)
p+1-p+8		UDP header (see note 2)
p+9-p+11		IEEE 802.2 LLC header

p+9		DSAP: the destination SAP obtained from the IEEE 802.2 LLC (X'80') subfield in the HPR Capabilities (X'61') control vector in the received XID3 (see note 3)
p+10		SSAP: the source SAP obtained from the IEEE 802.2 LLC (X'80') subfield in the HPR Capabilities (X'61') control vector in the sent XID3 (see note 4)
p+11		Control:
	X'03'	UI with P/F bit off
p+12-n		Remainder of PDU: NLP
		Note 1: Rules for encoding the IP header can be found in RFC 791.
		Note 2: Rules for encoding the UDP header can be found in RFC 768.

IP Format for NLPs in UI Frames		
Byte	Bit	Content
		Note 3: The User-Defined Address bit is considered part of the DSAP. The Individual/Group bit in the DSAP field is set to 0 by the sender and ignored by the receiver.
		Note 4: The User-Defined Address bit is considered part of the SSAP. The Command/Response bit in the SSAP field is set to 0 by the sender and ignored by the receiver.

7.0 Full Copyright Statement