FIBRE CHANNEL

ARBITRATED LOOP (FC-AL-2)
REV 5.4

working draft proposal
American National Standard
for Information Technology

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SECRETARIAT: Computer & Business Equipment Manufacturers Association

ABSTRACT: This standard defines functional requirements for an interoperable Arbitrated Loop topology to support the Fibre Channel standard.

NOTE: ***This is an internal working document of T11, a Task Group of Accredited Standards Committee X3. As such, this is not a completed standard. The contents are actively being modified by the T11 Task Group. This document is made available and may be reproduced for review and comment only. For current information on the status of this document contact the individuals shown below:***

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Changes in this document

Version 5.3

- added ARB(F7) for arbitrating without an AL_PA to allow for non-disruptive initialization.
- corrected minor items in the state tables.
- added transfer initiative Primitive Signals.
- added and removed ARByx Primitive Signal to identify the L_Port to be opened in y.
- added LPBfx Primitive Sequence to bypass all L_Port.
- changed SOFil to SOFiL to differentiate the 'I' from 'l'.
- added description to the Initialization Primitive Sequences in Figure 5.
- removed forward referencing footnotes (to FC-AL-2 fixes) and changed text accordingly.
- modified figure J.1 to show dual loops and two fabrics.
- added fairness fixes:
  + propagate at least three Idles when resetting the fairness window (to avoid losing a single Idle for clock skew).
  + if ARBx is received in the Monitoring State with x=AL_PA (an error since someone is using the same address) to avoid the fairness window from not being reset, the bullet 'x=AL_PA ...,' the current Fill Word is changed to Idle.
  + if the last L_Port in a fairness window gets opened while it is arbitrating, it must keep ARBx as current Fill Word. The change is to continue to modify the CFW according to normal rules as long as REQ(arbitrate as x) is active in the OPENED, XMITTED CLOSE, and RECEIVED CLOSE states.
  + if the last L_Port in a fairness window wins arbitration, but does not need access to the Loop (e.g., if arbitrating on more than one loop), the L_Port must go through the OPEN state (by transmitting OPNx where x=AL_PA of the L_Port) and then close the Loop by transmitting CLS).
  + the OPEN L_Port does not reset fairness window until it receives Idle (not when it transmits Idle).
- changed the OPENED and RECEIVED CLOSE states to transmit a CLS if an ARBx (where x = AL_PA of the L_Port--which implies an error situation) at the next appropriate Fill Word.
- added change to OPEN state to allow OPNfr to be issued subsequent to OPNyr (previously, if OPNfr was to be used, it could not follow an OPNyr).
- corrected table 7 (OPEN state) and the LPB line where x=AL_PA to state FC-2 FP/PSig/PSeq instead of the CFW. CFW was an error since the L_Port is open and may be in the middle of transmitting a frame.
- changed State Tables to use the CFW (instead of Idle) when Loss of Sync is detected.
- changed Annex I to reflect standard--transmit LIPs that are received.
- added and removed primitive signals to support RIP and FC-SL.
- modified initialization to use LISM instead of Idle to flush the loop.
- added tolerance to AL_TIME.
- softened the requirement to LIP and added a description of a controlled configuration in an annex.
- removed annex A (alternate BB_Credit FC-PH description)--now if FC-PH-2.
- added 10 second timer to select a Loop master.
- added Dynamic Half-Duplex capability based on a login bit.
- changed selective reset LIP to be allowed for public (as well as private) NL_Ports.
- corrected a recurring LIP during the OPEN-INIT state (if the L_Port knows that it sent it, it does not resend it).
- added new initialization text into 10.4 (not in this version).
- changed MONITORING state when bypassed; if loss of signal is detected, go to INITIALIZATION and send LIP(F8). The current text would require a timeout. This change notifies a loop when an error is detected.
- changed selective reset (LIP(AL_PD,AL_PS)) to include public L_Ports. Also added LIP(FF,AL_PS) to include a reset of all L_Ports (except the one at AL_PS).

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draft proposed American National Standard
for Information Technology —

Fibre Channel — Arbitrated Loop

Secretariat

Computer and Business Equipment Manufacturers Association

Approved xxxx xx, 199x

American National Standards Institute, Inc

Abstract

This standard defines functional requirements for an inter-operable Arbitrated Loop topology to support the Fibre Channel standard.

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Foreword (This foreword is not part of American National Standard X3.272-199x.)

This standard defines functional requirements for an inter-operable Arbitrated Loop topology for Fibre Channel.

This standard was prepared by Task Group X3T11 (formerly X3T9.3) of the Accredited Standards Committee X3 during 1993. The standard process started in 1989. This document includes annexes that are informative and are not considered part of the standard.

Requests for interpretation, suggestions for improvements or addenda, or defect reports are welcome. They should be sent to the X3 Secretariat, Computer and Business Equipment Manufacturers Association, 1250 Eye Street, NW, Suite 200, Washington, DC 20005-3922.

This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee on Information Processing Systems, X3. Committee approval of the standard does not necessarily imply that all committee members voted for approval. At the time it approved this standard, the X3 Committee had the following members:

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NOTE: The developers of this standard have requested that holders of patents that may be required for the implementation of the standard, disclose such patents to the publisher. However, neither the developers nor the publishers have undertaken a patent search in order to identify which, if any patents, may apply to this standard. No position is taken with respect to the validity of any claims or any patent rights that may have been disclosed. Details may be obtained from the publisher concerning any statement of patents and willingness to grant a license on a non-discriminatory basis and with reasonable terms and conditions to applicants desiring to obtain such a license.

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Introduction

This American National Standard specifies an enhancement to the signaling protocol of the Fibre Channel Physical and Signaling Interface (FC-PH), ANSI X3.230, to support communication among two or more Ports without using the Fabric topology. The following diagram shows the relationship of this document to other parts of Fibre Channel. The roadmap is intended to show the general relationship of documents to one another, not a hierarchy, protocol stack, or system architecture.

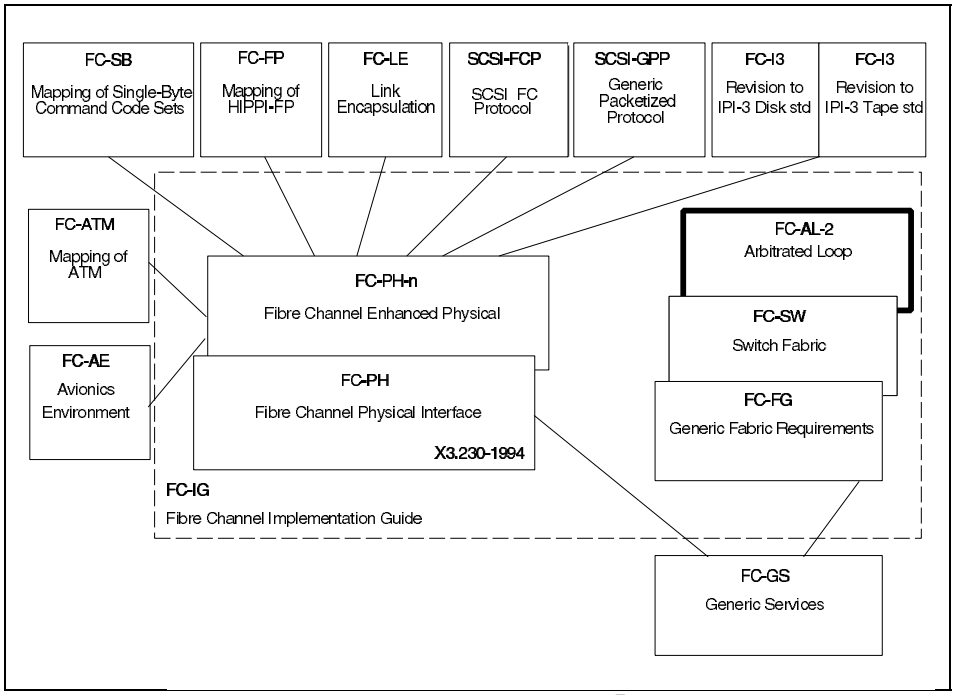

Figure 0 – Fibre Channel Roadmap

FC-AL features enhanced Ports, called L_Ports, that arbitrate to access an Arbitrated Loop. Once an L_Port wins arbitration, a second L_Port may be opened to complete a single point-to-point circuit (i.e., communications path between two L_Ports). When the two connected L_Ports release control of the Arbitrated Loop, another point-to- point circuit may be established. An L_Port discovers its environment and works properly, without outside intervention, with an F_Port, an N_Port, or with other L_Ports.

There is no change to the framing protocol of ANSI X3.230, FC-PH, however, modification to the Port hardware is required to transmit, receive, and interpret the new Arbitrated Loop Primitive Signals and Sequences.

The clauses in this document are organized as follows:

Clause 1 describes the scope.

Clause 2 lists the normative references.

Clause 3 provides descriptions and conventions.

Clause 4 provides an overview and general description of FC-AL.

Clause 5 describes the Arbitrated Loop Physical Address.

Clause 6 describes the FC-AL Ordered Sets.

Clause 7 describes the Primitive Signals and Sequences.

Clause 8 describes the operation of an L_Port including the state machine.

Clause 9 provides a table representation of the FC-AL states.

Clause 10 describes the Port initialization procedure.

draft proposed American National Standard for Information Technology

Fibre Channel — Arbitrated Loop Topology (FC-AL-2)

1 Scope

This American National Standard for FC-AL specifies signaling interface enhancements for ANSI X3.230, FC-PH to allow L_Ports to operate with an Arbitrated Loop topology. This standard defines L_Ports that retain the functionality of Ports as specified in ANSI X3.230, FC-PH. The Arbitrated Loop topology attaches multiple communicating points in a loop without hubs and switches.

The Arbitrated Loop topology is a distributed topology where each L_Port includes the minimum necessary function to establish a circuit. A single FL_Port connected to an Arbitrated Loop allows multiple NL_Ports to attach to a Fabric.

L_Ports support the following two operating modes since they may be attached directly to an F_Port or an N_Port (i.e., ports which do not support the Arbitrated Loop) or to an Arbitrated Loop:

— when an L_Port is connected with an N_Port or an F_Port, the L_Port follows the protocol defined in ANSI X3.230, FC-PH.

— when an L_Port is operating on a Loop with at least one other L_Port, the L_Port modifies its behavior to use the protocol extensions specified in this standard.

Each L_Port uses a self-discovering procedure to find the correct operating mode without the need for external controls.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

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2.1 Approved references

ANSI X3.272-1996, *Information Technology — Fibre Channel — Arbitrated Loop (FC-AL)*

ANSI X3.289-1996, *Information Technology — Fibre Channel — Fabric Requirements (FC-FG)*

ANSI X3.230-1994, *Infomration Technology — Fibre Channel —* Physical and Signaling Interface (FC-PH)

2.2 References under development

At the time of publication, the following referenced standards were still under development. For information on the current status of the documents, or regarding availability, contact the relevant standards body or other organization as indicated.

X3 Project 959-D, *Information Technology — Fibre Channel — Switch Topologies and Switch Control (FC-SW)*[1]

X3 Project 901-D, *Information Technology — Fibre Channel — Physical and Signaling Interface (FC-PH-2)*[1]

X3 Project 1119-D, *Information Technology — Fibre Channel — Physical and Signaling Interface (FC-PH3-)*[1]

3 Definitions and conventions

3.1 Definitions

For the purpose of this standard, the definitions in clause 3 of ANSI X3.230, FC-PH and the following definitions apply. Definitions in this clause take precedence over any definitions in ANSI X3.230, FC-PH.

3.1.1 **Alias AL_PA**: Multiple Loop addresses that can be recognized by an L_Port.

3.1.2 **Arbitrated Loop:** A Fibre Channel topology where Ports use arbitration to gain access to the Loop.

3.1.3 **Arbitrated Loop Physical Address (AL_PA):** A unique one-byte valid value assigned (according to table 1) during Loop Initialization to each NL_Port or FL_Port on a Loop.

3.1.4 **Arbitrated Loop Destination Address (AL_PD):** The Arbitrated Loop Physical Address of the L_Port on the Loop that should receive the Primitive Signal. For example, the AL_PD is the y value of the OPNyx or OPNyy Primitive Signal.

3.1.5 **Arbitrated Loop Source Address (AL_PS):** The Arbitrated Loop Physical Address of the L_Port on the Loop that transmitted the Primitive Signal. For example, the AL_PS is the x value of the OPNyx Primitive Signal.

3.1.6 **CFW substitution:** A term used in the state tables for those states where arbitration can occur (i.e., ARBITRATING, OPENED, XMITTED CLOSE, and RECEIVED CLOSE). The current Fill Word is modified based on the contents of the ARBx (see ARBITRATING state).

3.1.7 **circuit:** A bidirectional path that allows communication between two L_Ports.

3.1.8 **close:** A procedure used by an L_Port to relinquish control of the Loop.

3.1.9 **current Fill Word:** The Fill Word currently selected by the LPSM to be transmitted when needed. (See 8.4.)

3.1.10 Dynamic Half-Duplex: A procedure to change a full-duplex link to a half-duplex link. (See 7.5).

3.1.11 **Fill Word:** A Transmission Word which is an Idle (i.e., K28.5 D21.4 D21.5 D21.5) or an ARBx Primitive Signal. These words are transmitted between frames, Primitive Signals, and Primitive Sequences to keep a fibre active. (See ANSI X3.230, FC-PH, clause 17.)

3.1.12 **F/NL_Port:** An NL_Port that recognizes OPN(00,x) and provides Fibre Channel services in the absence of an FL_Port.

3.1.13 **full-duplex:** Communication model 2 referred to as *duplex* in ANSI X3.230, FC-PH. Both L_Ports are allowed to transmit and receive Data frames.

3.1.14 **half-duplex:** Communication model 1 in ANSI X3.230, FC-PH. Only one L_Port is allowed to transmit Data frames.

3.1.15 **Loop:** The Arbitrated Loop described in this document.

3.1.16 **Loop Failure:** Loss of sync for greater than R_T_TOV or loss of signal. (See ANSI X3.230, FC-PH, 12.1.3.)

3.1.17 **L_Port:** Either an FL_Port or an NL_Port as defined in ANSI X3.230, FC-PH, 3.1. Without the qualifier "Public" or "Private," an NL_Port is assumed to be a Public NL_Port.

3.1.18 **monitor:** A procedure used by an L_Port to route received Transmission Words.

3.1.19 **non-L_Port:** A Port that does not support the Loop functions defined in this standard. (See *Port* in ANSI X3.230, FC-PH.)

3.1.20 non-participating mode: An L_Port that is not active on the Loop (i.e., it does not have a valid AL_PA). (See 8.3.1.)

3.1.21 open: A procedure used by an L_Port to establish a circuit.

3.1.22 participating mode: An L_Port that is active on the Loop (i.e., it does have a valid AL_PA). (See 8.3.1.)

3.1.23 Port_Name: A unique 64-bit identifier as defined in the LOGI or ACC frame. (See ANSI X3.230, 23.6.4.)

3.1.24 Private Loop: A Loop that does not include a participating FL_Port. (See figure 1 and annex J.)

3.1.25 Private NL_Port: An NL_Port that shall not attempt a Fabric Login and shall not transmit OPN(00,x). (See figure 1 and 5.2.)

3.1.26 Public Loop: A Loop that includes a participating FL_Port and may contain both Public and Private NL_Ports. (See figure 1 and annex J.)

3.1.27 Public NL_Port: An NL_Port that shall attempt a Fabric Login. (See figure 1 and 5.2.)

3.1.28 received Transmission Word: a word that is recognized by the receiver. Transmission Words which are not recognized, are ignored by the receiver.

3.1.29 replicate frame: A Class 3 frame which is received by multiple NL_Ports. (See 7.3.)

3.1.30 transfer: A procedure used by the L_Port that is in the OPEN state to establish a circuit with another L_Port without going through an arbitration cycle (i.e., the L_Port goes from the OPEN to the TRANSFER to the OPEN state).

3.2 Editorial conventions

In FC-AL, many conditions, mechanisms, sequences, events or similar terms are printed with the first letter of each word in upper case and the rest lower case (e.g., Loop). States are defined in all upper case letters. Any lower case words not defined in 3.1 have the normal technical English meaning.

In case of conflicts between text, tables, and figures, the following precedence shall be used: text, tables, figures.

The word, *shall*, when used in this standard, states a mandatory rule or requirement. The word, *may*, when used in this standard, states an optional rule.

Each individual entry that appears within parentheses behind the Primitive Signals ARBx and OPNy represents the hexadecimal values of an AL_PA.

3.3 Abbreviations and acronyms

ACCESS **Access** flag – a two-valued variable (i.e., *0*/*1*) to indicate access fairness history

AL_PA **A**rbitrated **L**oop **P**hysical **A**ddress (e.g., the x value in ARBx)

AL_PD **A**rbitrated **L**oop **D**estination Physical Address (e.g., the y value in OPNyx and OPNyy)

AL_PS **A**rbitrated **L**oop **S**ource Physical Address (e.g., the x value in OPNyx)

AL_TIME **A**rbitrated **L**oop **time**out value (See 8.2.2.)

ARBx **Arb**itrate Primitive Signal – any of the ARB Primitive Signals (x is the AL_PA of the arbitrating L_Port)

ARB_PEND **Arb**itration **PEND**ing flag – a two-valued variable (i.e., 0/1) to help an L_Port remember that it has transmitted one or more ARBx Primitive Signals.

ARB_WON **Arb**itration **Won** flag – a two-valued variable (i.e., *0*/*1*) that identifies the L_Port that won arbitration

Available_BB_Credit **Available B**uffer-to-**B**uffer **Credit** – the difference between the number of R_RDYs received and the number of frames sent in a single circuit.

BB_Credit **B**uffer-to-**B**uffer **Credit** – the Login credit which represents the number of frames that may be transmitted before receiving an R_RDY.

CLS **Cl**o**s**e Primitive Signal

DUPLEX **Duplex** flag – a two-valued variable (i.e., *0*/*1*) to indicate half-duplex or full-duplex mode, respectively.

DHD **D**ynamic **H**alf-**D**uplex Primitive Signal – used to place the Loop into half-duplex mode of operation.

DHD_RCV **D**ynamic **H**alf-**D**uplex **R**e**C**ei**V**ed flag – a two valued variable (i.e., *0*/*1*) to indicate that the L_Port in the OPENED state has recognized DHD.

EE_Credit **E**nd-to-**E**nd **Credit** – the Login credit which represents the number of receive buffers that the recipient L_Port has allocated to this originating L_Port.

LIP **L**oop **I**nitialization **P**rimitive Sequence – any of the LIP Primitive Sequences

LIPyx **L**oop **I**nitialization **P**rimitive Sequence to reset an L_Port at AL_PA = y

LPB **L**oop **P**ort **B**ypass Primitive Sequence – either LPBfx or LPByx Primitive Sequences

LPBfx **L**oop **P**ort **B**ypass Primitive Sequence – used to bypass all L_Port

LPByx **L**oop **P**ort **B**ypass Primitive Sequence – used to bypass an L_Port at y = AL_PA

LPE **L**oop **P**ort **E**nable Primitive Sequence – either LPEfx or LPEyx Primitive Sequences

LPEfx **L**oop **P**ort **E**nable Primitive Sequence – used to enable all bypassed L_Ports (f = hex 'FF')

LPEyx **L**oop **P**ort **E**nable Primitive Sequence – used to enable a bypassed L_Port at y = AL_PA

LIFA **L**oop **I**nitialization **F**abric **A**ssigned – Loop Initialization Sequence

LIHA **L**oop **I**nitialization **H**ard **A**ssigned – Loop Initialization Sequence

LILP **L**oop **I**nitialization **L**oop **P**osition – Loop Initialization Sequence

LIPA **L**oop **I**nitialization **P**reviously **A**cquired – Loop Initialization Sequence

LIRP **L**oop **I**nitialization **R**eport **P**osition – Loop Initialization Sequence

LISA **L**oop **I**nitialization **S**oft **A**ssigned – Loop Initialization Sequence

LISM **L**oop **I**nitialization **S**elect **M**aster – Loop Initialization Sequence

LP_BYPASS **L**oop **P**ort **Bypass**ed flag – a two valued variable (i.e., *0*/*1*) to indicate if an L_Port has been bypassed.

LPSM **L**oop **P**ort **S**tate **M**achine

MRKtx **Mar**k Primitive Signal

MK_TP **M**ar**k Typ**e – used to identify the type of Mark Primitive Signal (e.g., clock synchronization)

OPNr **Ope**n Replicate Primitive Signal – either OPNfr or OPNyr Primitive Signals

OPNfr **Ope**n Primitive Signal – broadcast replicate

OPNyr **Ope**n Primitive Signal – selective replicate

OPNy **Ope**n Primitive Signal – either OPNyx or OPNyy Primitive Signals

OPNyx **Ope**n Primitive Signal – full-duplex

OPNyy **Ope**n Primitive Signal – half-duplex

REPLICATE **Replicate** flag – a two valued variable (i.e., *0*/*1*) to indicate if the L_Port has recognized OPNr while in the MONITORING or ARBITRATING states.

SOFiL **S**tart_**o**f_**F**rame Primitive Signal (K28.5 D21.5 D22.2 D22.2) used during Loop Initialization.

4 Structure and concepts

This clause provides an overview of the structure, concepts, and mechanisms that allow two or more L_Ports to communicate without using a Fabric topology. Readers unfamiliar with FC-AL should read or scan clauses 1 and 4 before attempting to master the detailed material in clauses 5 through 10.

4.1 Overview

The Loop guarantees in-order delivery of frames in all Classes of Service when the source and destination are on the same Loop. Frames transmitted from an NL_Port to an FL_Port are received at the FL_Port in order and frames from an FL_Port are received in the order transmitted by the FL_Port to an NL_Port on the Loop. Out of order frames may be received at a destination NL_Port, but that out-of-order characteristic is not caused by the FL_Port or the Loop.

FC-AL is a serial data channel, structured for low-cost connectivity, that provides a logical bidirectional, point-to-point service between two L_Ports. Each L_Port represents a communication point. The additional functions, that are added to allow an N_Port or F_Port to operate on a Loop, permit the L_Ports to form a simple, blocking, non-meshed, switching environment.

— Blocking refers to the number of circuits that can be concurrently active. Only one pair of L_Ports may communicate at one time although there may be up to 127 participating L_Ports attached on one Loop. All other communication must wait (i.e., is blocked).

— Non-meshed refers to the attribute of a Loop where there is exactly one path on each Loop between L_Ports. Non-meshed implies that any single fibre problem may stop all activity on the Loop. Meshed, in this context, means that there may be alternate paths available between L_Ports.

— Switching refers to the Loop circuitry added to each L_Port compared to a non-L_Port. The circuitry acts as a two-port switch where information received on the inbound fibre of the L_Port is directed to either the local FC-2 function or placed on the outbound fibre for another L_Port to process.

The Loop supports a maximum of one point-to-point circuit at a time. When two L_Ports are communicating, the Loop topology supports simultaneous, symmetrical, bidirectional flow between the two L_Ports is supported. All other L_Ports are monitoring the Loop.

Unlike the Fabric topology where a circuit is established only for a dedicated connection, a circuit must be established between two L_Ports on the Loop before the FC-PH framing protocol may be used. The two L_Ports may use the framing protocol and any Class of Service appropriate for their implementations and for the FC-4 protocol being used. Other L_Ports on the same Loop may form their own circuit after the current circuit is closed.

The Loop supports all Classes of Service as specified in ANSI X3.230, FC-PH, 4.3. Individual L_Ports may choose to implement, at the FC-2 level, only a subset of the Classes of Service available. Such an implementation does not affect the operation of the Loop protocol.

4.2 General description

In a Fabric topology, one or more Fabric Element(s) is required to connect more than two Ports together. (See ANSI X3.289, FC-FG, for the minimum requirements of a Fabric.)

Figure 1 shows two independent Loop configurations each with multiple L_Ports connected. Each line in the figure between L_Ports represents a single fibre. The first configuration shows two Loops which include two and six NL_Ports only (i.e., Private Loops). The second configuration shows a Loop which includes one FL_Port (i.e., a Public Loop) and five NL_Ports (either Public or Private NL_Ports). (See annex J.)

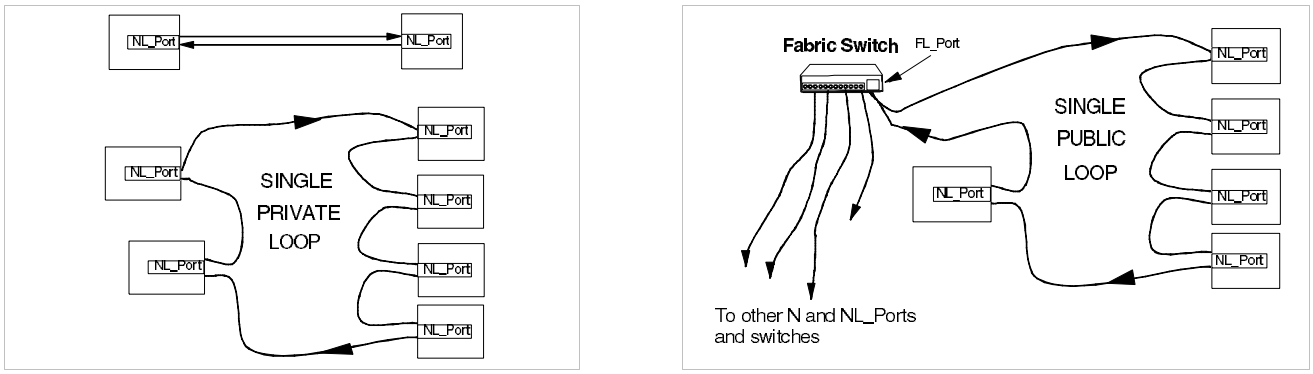


Figure 1 — Examples of the Loop topology

The Loop topology reduces the number of transceivers required to interconnect L_Ports to one transceiver per L_Port. Up to 127 L_Ports may be in participating mode on one Loop.

The different topologies have certain pertinent distinguishing characteristics.

— The **point-to-point topology** is non-blocking. Each N_Port may transmit frames to the other at any time within the limits of the implemented protocols of the N_Ports. Although this provides instantaneous access to the other N_Port, it usually under-utilizes the resources provided by the N_Ports.

The number of transceivers needed to completely interconnect *n* N_Ports using multiple links may be calculated using the formula: $t = n (n - 1)$ where *t* and *n* represent the number of transceivers and N_Ports, respectively. For example, to connect six (6) N_Ports requires 30 transceivers.

Also, if a link in a point-to-point topology fails, communication between that pair of Ports stops. Communication between other point-to-point connected Ports continues.

— The **Fabric topology** may be configured to be non-blocking between any two N_Ports. It is commonly recognized that most data processing-type Nodes cannot sustain high-speed data transfer for long periods of time to all peripheral devices (although there may be some exceptions). A Fabric offers a way to take advantage of these natural pauses in communication, allowing fewer interconnects. The available bandwidth is shared between the N_Ports, but this sharing adds contention and therefore a management function is required.

One advantage for the Fabric topology is that when there is at least one free F_Port in the Fabric, a new N_Port can be added to the free F_Port without disrupting the remaining N_Ports. The new N_Port has the potential to communicate with all other N_Ports in the Fabric. However, adding an N_Port does not guarantee that the new N_Port can communicate with any of the currently attached N_Ports. (See ANSI X3.289, FC-FG.)

Because a Fabric topology permits multiple paths between any two F_Ports in the Fabric (i.e., the meshing capability of the Fabric topology), a Fabric topology may be more robust. For a Node with only one N_Port, there is always a single point of failure at the link to the Fabric Element.

— The **Loop topology** functions are the result of reducing the Fabric topology to its simplest form. There is exactly one link bandwidth to share among all L_Ports. This makes the Loop the ultimate blocking topology, yet it retains considerable connectivity. There can be only one active circuit at a time, independent of the number of L_Ports on a Loop. New L_Ports can be added at any time, although only a maximum of 127 may be participating. Should any link in a Loop fail, communication between all L_Ports stops on that Loop. (See annex C.)

  Fabric management is reduced to a minimum with the remaining functions distributed in each L_Port on the Loop. This eliminates the central management function of a Fabric and at least one-half of the transceivers compared to a Fabric topology. Once communication is established between two L_Ports, the normal ANSI X3.230, FC-PH protocol is used for all operations.

The Loop topology and the Fabric topology together provide a compromise between connectivity and performance. A number of small Loops may be connected through a small Fabric. For example, four sixteen-port Loops (one FL_Port and fifteen NL_Ports) may be connected through a four-port Fabric to achieve a connectivity of sixty L_Ports with better performance than if all sixty NL_Ports were on one Loop.

4.3 Access fairness algorithm

The protocol for the Loop permits each L_Port to continuously arbitrate to access the Loop. A priority is assigned to each participating L_Port based on the Arbitrated Loop Physical Address (AL_PA). As with other prioritized protocols, this could lead to situations where the lower priority L_Ports cannot gain access to the Loop. The access fairness algorithm sets up an access window in which all L_Ports are given an opportunity to arbitrate and win access to the Loop. When all L_Ports have had an opportunity to access the Loop once, a new access window is started. An L_Port may arbitrate again and eventually win access to the Loop in the new access window. Not every L_Port is required to access the Loop in any one access window.

When an L_Port which uses the access fairness algorithm has arbitrated for and won access to the Loop, the L_Port shall not arbitrate again until at least two Idles have been transmitted by the L_Port. The time between the first L_Port to win arbitration and transmitting an Idle is an access window. A special arbitration Primitive Signal (i.e., ARB(F0)) is used to prevent an early reset of the access window. The details of the access fairness algorithm are contained in the Loop state machine.

The access fairness algorithm does not limit the time that an L_Port controls the Loop once it wins arbitration, just as ANSI X3.230, FC-PH does not limit the time for a Class 1 connection. However, if access is denied longer than E_D_TOV, the access window is reset and an L_Port may begin arbitrating.

Although all NL_Ports shall implement the fairness algorithm, neither FL_Ports nor NL_Ports are required to use the fairness algorithm at all times. For example, if one L_Port requires more Loop accesses than the other L_Ports, that L_Port may choose to be unfair. The decision when to be fair or unfair is beyond the scope of this standard. (See annex D.)

4.3.1 Access fairness for NL_Ports

To provide equal access to the Loop for all NL_Ports, it is recommended that each NL_Port use the access fairness algorithm. When an NL_Port is using the access fairness algorithm, it is called a *fair* NL_Port.

When a fair L_Port has arbitrated for and won access to the Loop and does not detect that another L_Port is arbitrating, that L_Port may keep the existing circuit open indefinitely or close that circuit and retain ownership of the Loop (i.e., without re-arbitrating) to open another L_Port on the Loop.

When a fair NL_Port has access to the Loop and detects that another L_Port is arbitrating, the NL_Port may close the Loop at the earliest possible time. The NL_Port shall close the Loop and arbitrate again in the next access window before opening a different L_Port.

4.3.2 Access unfairness for NL_Ports

The configuration of some Loops may require that certain NL_Ports have more access to the Loop than just once per access window. Examples of these NL_Ports include, but are not limited to, a subsystem controller or a file server.

An NL_Port may be initialized (or may temporarily choose) not to use the access fairness algorithm. When an NL_Port is not using the fairness algorithm, it is called an *unfair* NL_Port. The decision whether to participate in access fairness is beyond the scope of this standard. (See annex D.)

When an unfair L_Port has arbitrated for and won access to the Loop and does not detect that another L_Port is arbitrating, that L_Port may keep the existing circuit open indefinitely or close that circuit and retain ownership of the Loop (i.e., without re-arbitrating) to open another L_Port on the Loop.

When an unfair NL_Port controls the Loop and detects that another L_Port is arbitrating, the unfair NL_Port may close the Loop at the earliest possible time. The unfair NL_Port may retain ownership of the Loop (i.e., without re-arbitrating) and open another L_Port on the Loop.

4.3.3 Access unfairness for FL_Ports

A participating FL_Port is always the highest priority L_Port on the Loop based on its AL_PA. An FL_Port is exempted from using access fairness algorithm because the majority of its traffic is with the rest of the Fabric.

When an FL_Port controls the Loop and detects that another NL_Port is arbitrating, the FL_Port may close the Loop at the earliest possible time. Because the FL_Port has the highest priority and is exempted from fairness, it will always win arbitration. Therefore, if communication is required with another NL_Port, the FL_Port may retain its access to the Loop (i.e., without re-arbitrating) and open another NL_Port on the Loop.

4.4 Relationship to ANSI X3.230, FC-PH

If a Port uses FC-AL, it extends the FC-2 and FC-1 functions of ANSI X3.230, FC-PH. Figure 2 shows logically where the Loop (FC-AL) function is located. This functional level does not have a formally defined interface to the other levels.

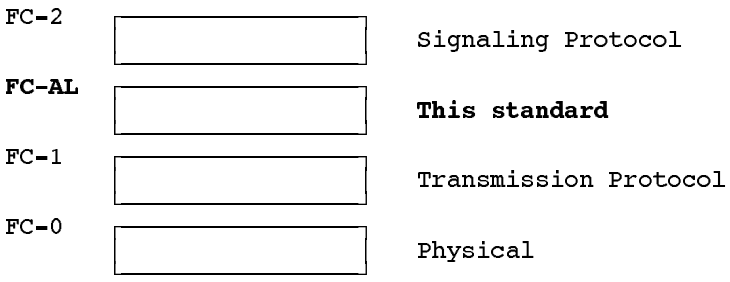


Figure 2 — FC-PH with Arbitrated Loop addition

When two L_Ports are communicating, the L_Ports may use all of the functions specified in ANSI X3.230, FC-PH. The following list is a clause-by-clause analysis of the differences between N_Ports or F_Ports and NL_Ports or FL_Ports, respectively. The Loop:

— supports communication models 1 and 2 identified in ANSI X3.230, FC-PH, 4.6, but it does not support model 3. Any two L_Ports may operate in half-duplex mode during one circuit. The direction of the half-duplex mode may be changed by establishing a new circuit in the opposite direction;

— adds new error detection or recovery protocols in 8.3 in addition to those identified in ANSI X3.230, FC-PH, 4.14, and related clauses;

— places no limit on the use of any one type of transmitter (although they shall all be of the same data rate) for the cable plant of a Loop. Some requirements (e.g., Open Fibre Control) may prevent interoperability when mixed on a single Loop. Annex C shows a multiple Loop example to achieve interoperability for all transmitters. (See annex C and ANSI X3.230, FC-PH, clauses 5 through 10);

— specifies that all NL_Ports and the optional FL_Port on a Loop shall use the same data rate. (See ANSI X3.230, FC-PH, clause 5.) Also, the normal ANSI X3.230, FC-PH buffer-to-buffer flow control is not used for L_Ports that are monitoring the Loop. (See 8.3.6);

— expands the number of Ordered Sets beyond those specified in ANSI X3.230, FC-PH, clause 11. (See clause 6);

— expands the number of Primitive Signals and Sequences beyond those specified in ANSI X3.230, FC-PH, clause 16. (See clause 7);

— extends the Ordered Sets that may be deleted to include Idle, ARBx, and all Primitive Sequences. (See 8.3.3);

— specifies the Primitive Signals that may be inserted on a Loop between frames for clock skew management. (See 8.3.3);

— allows clock skew management by L_Ports on a Loop by requiring that an FL_Port in the OPEN or OPENED state shall transmit at least six (6) Primitive Signals between Class 2 or Class 3 frames. In a Class 1 connection, the clock skew needs to be managed between the two NL_Ports (i.e., from one end of the circuit to the other end);

— defines a local physical address and native address identifier assignment algorithms when an FL_Port is not present on a Loop. (See clause 10);

— requires a minimum payload size of 132 bytes for Loop Initialization. (See 10.4);

— permits an L_Port to manage a separate BB_Credit for each L_Port on the Loop or the L_Port may choose to use a single value for BB_Credit. The single value shall be the minimum value for all L_Ports;

— requires that the L_Port set the "Alternate BB_Credit Management" bit to *1* in the N_Port Common Service Parameters during Login. (See ANSI X3.230, FC-PH, 23.6.3 and ANSI X3.297-199x, FC-PH-2, 26.5);

— permits a circuit to be terminated when Available_BB_Credit is unbalanced;

— requires that each L_Port is capable of mapping the S_ID in each frame it receives to the AL_PA of the L_Port that transmitted this frame;

— requires that the destination of a connect request (SOFc1) sent through an FL_Port is to a Port not on the Loop; the FL_Port is not able to open another NL_Port on the same Loop (this would require three open L_Ports);

— requires a Loop Initialization Extended Link Service Sequence to be used during the initialization procedure; and,

— allows an NL_Port (in the absence of an FL_Port) to act as an F/NL_Port. The F/NL_Port shall provide the Fabric Login service associated with well-known address identifier hex 'FFFFFE'. The F/NL_Port may also provide services associated with other well-known address identifiers.

When a circuit has been established between two L_Ports (see ANSI X3.230, FC-PH, clause 26 for flow control), FC-2 uses:

— the point-to-point topology model, when both communicating NL_Ports are on the same Loop;

— the Fabric topology model, when one communicating port is outside the Loop; and,

— the Primitive Sequences NOS, OLS, LR, and LRR operate as specified in ANSI X3.230, FC-PH, clause 16.

5 Addressing

5.1 Arbitrated Loop Physical Address (AL_PA) and flags

Each L_Port (if it chooses to participate on the Loop, see 8.3.1) shall be assigned a local Arbitrated Loop Physical Address (AL_PA) during the initialization procedure. When an FL_Port is not present on a Loop, the assigned AL_PA shall be extended and used as its native address identifier. (See clause 10.) The AL_PA establishes the priority of an arbitrating L_Port (i.e., the lower the AL_PA, the higher the priority).

Each L_Port shall use an AL_PA value that results in neutral disparity. (See ANSI X3.230, FC-PH, clause 11). The algorithm described below or in table 1 provides a means for the L_Port to select a valid AL_PA.

The AL_PA shall be a valid data character as specified in ANSI X3.230, FC-PH, clause 11 that does not change the current running disparity of a Transmission Word. The algorithm below is dependent on the FC-1 naming convention for an information byte in ANSI X3.230, FC-PH, 11.1 and table 26, identified as Dxx.y. The xx portion of the FC-1 naming convention is based on bits identified as E, D, C, B, and A in ANSI X3.230, FC-PH, 11.1, in that order. The y portion of the FC-1 naming convention is based on bits identified as H, G, and F in ANSI X3.230, FC-PH, 11.1, in that order. A decimal value is assigned to each bit combination with the range of 0 to 31 for xx and 0 to 7 for y, respectively. The entire range for valid data characters using the FC-1 naming convention is D00.0 through D31.7.

Disparity for a valid data character is calculated as follows:

— arrange an information byte in the manner prescribed for the naming convention in ANSI X3.230, FC-PH, 11.1, to obtain the Dxx.y data byte name;

— if the xx portion of a valid data character is (in decimal) 0, 1, 2, 4, 8, 15, 16, 23, 24, 27, 29, 30, or 31, set HI to 1. If the xx portion is (in decimal) 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 25, 26, or 28, set HI to 0;

— if the y portion of a valid data character is (in decimal) 0, 4, or 7, set LO to 1. If the y portion is (in decimal) 1, 2, 3, 5, or 6, set LO to 0; and,

— compute the XOR function for HI and LO (i.e., XOR(HI,LO)).

If the computed value of the XOR function is 0, the value is disparity neutral and is a valid AL_PA. If the computed value of the XOR function is 1, the value is disparity biased and the FC-2 byte is not a valid AL_PA.

Table 1 identifies with an asterisk (*) each 8B/10B character that has neutral disparity ordered by the Dxx.y naming convention. The right-most column shows the FC-2 byte notation values for each row with neutral disparity in table 1.

Table 1 — 8B/10B characters with neutral disparity

D xx . y	y								
xx	0	1	2	3	4	5	6	7	Hex value
00	*				*			*	00, 80, E0
01	*				*			*	01, 81, E1
02	*				*			*	02, 82, E2
03		*	*	*		*	*		23, 43, 63, A3, C3
04	*				*			*	04, 84, E4
05		*	*	*		*	*		25, 45, 65, A5, C5
06		*	*	*		*	*		26, 46, 66, A6, C6
07		*	*	*		*	*		27, 47, 67, A7, C7
08	*				*			*	08, 88, E8
09		*	*	*		*	*		29, 49, 69, A9, C9
10		*	*	*		*	*		2A, 4A, 6A, AA, CA
11		*	*	*		*	*		2B, 4B, 6B, AB, CB
12		*	*	*		*	*		2C, 4C, 6C, AC, CC
13		*	*	*		*	*		2D, 4D, 6D, AD, CD
14		*	*	*		*	*		2E, 4E, 6E, AE, CE
15	*				*			*	0F, 8F, EF
16	*				*			*	10, 90, F0
17		*	*	*		*	*		31, 51, 71, B1, D1
18		*	*	*		*	*		32, 52, 72, B2, D2
19		*	*	*		*	*		33, 53, 73, B3, D3
20		*	*	*		*	*		34, 54, 74, B4, D4
21		*	*	*		*	*		35, 55, 75, B5, D5
22		*	*	*		*	*		36, 56, 76, B6, D6
23	*				*			*	17, 97, F7
24	*				*			*	18, 98, F8
25		*	*	*		*	*		39, 59, 79, B9, D9
26		*	*	*		*	*		3A, 5A, 7A, BA, DA
27	*				*			*	1B, 9B, FB
28		*	*	*		*	*		3C, 5C, 7C, BC, DC
29	*				*			*	1D, 9D, FD
30	*				*			*	1E, 9E, FE
31	*				*			*	1F, 9F, FF
TOTAL 134	13	19	19	19	13	19	19	13	

LEGEND: * = character with neutral disparity

The assignment of the 134 neutral disparity values from table 1 within a Loop is as follows:

hex '00': (1) AL_PA for FL_Port or alias AL_PA of F/NL_Port

Highest priority.

AL_PA hex '00' shall be assigned to the FL_Port in participating mode. The maximum number of FL_Ports in participating mode on a single Loop shall not exceed one. Additional FL_Ports may be present, but they shall be in non-participating mode.

If there is no participating FL_Port on the Loop, a participating NL_Port may accept this value as an alias AL_PA for its LPSM, but not as its only AL_PA.

hex '01' through hex 'EF': (126) AL_PA for NL_Ports

Descending priority is assigned as AL_PA values increase in the range from hex '01' through hex 'EF'. All valid values in this range are lower in priority than hex '00'.

Each participating NL_Port shall be assigned one valid AL_PA in this range. The maximum number of participating NL_Ports on a single Loop shall not exceed 126.

hex 'F0': (1) Value used for fairness

Value hex 'F0' is the next lower priority outside the range hex '00' through hex 'EF'. Hex 'F0' shall only be used for the access fairness algorithm and during Loop Initialization.

hex 'F1' through hex 'F6': (0) Reserved

hex 'F7': (1) Value used as a flag in LIP or ARB to indicate L_Port is initializing (i.e., no AL_PA).

hex 'F8': (1) Value used as a flag in LIP to indicate error detected at the receiver of the L_Port.

hex 'F9' through hex 'FE': (3) Reserved

hex 'FF': (1) Value used to address all L_Ports in OPNfr, LBBfx, and LPEfx.

5.2 Native Address Identifier

A native address identifier shall be assigned to each participating NL_Port (up to the maximum of 126 NL_Ports) with the following characteristics:

- the low-order byte (bits 7-0) of the native address identifier is the AL_PA of the L_Port. The AL_PA shall be unique on a Loop, shall be in the range of hex '01' through hex 'EF', and shall be valid according to table 1.

- all Private NL_Ports shall have the upper two bytes of their native address identifier (bits 23-8) equal to hex '0000'.

- all Public NL_Ports shall have the upper two bytes of their native address identifier (bits 23-8) equal to the upper two bytes of the native address identifier of the FL_Port (hex 'XXXX00'). The FL_Port shall acquire this value (which shall not equal hex '000000') from its Fabric Element. The upper two bytes shall be unique for each Loop to allow multiple Loops to attach to the same Fabric.

  If an FL_Port is not present, these upper two bytes shall be set to zero (hex '0000').

- a native address identifier may be assigned to another NL_Port if a participating NL_Port enters non-participating mode.

6 FC-AL Ordered Sets

Table 2 specifies the Ordered Sets that shall be used by the Loop as additional Primitive Signals. (See ANSI X3.230, FC-PH, 11.4.) Table 3 specifies the Ordered Sets that shall be used by the Loop as additional Primitive Sequences. (See clause 7.)

Table 2 — Primitive Signals

Primitive Signal		Beginning RD	Ordered Set
Arbitrate as x	(ARBx)	Negative	K28.5 D20.4 AL_PS AL_PS
Arbitrate (F0) fairness	(ARB)	Negative	K28.5 D20.4 D16.7 D16.7
Arbitrate (F7) no AL_PA	(ARB)	Negative	K28.5 D20.4 D23.7 D23.7
Close	(CLS)	Negative	K28.5 D5.4 D21.5 D21.5
Dynamic Half-Duplex	(DHD)	Negative	K28.5 D10.4 D00.0 D00.0
Mark	(MRKtx)	Negative	K28.5 D31.2 MK_TP AL_PS
Open full-duplex	(OPNyx)	Negative	K28.5 D17.4 AL_PD AL_PS
Open half-duplex	(OPNyy)	Negative	K28.5 D17.4 AL_PD AL_PD
Open broadcast replicate	(OPNfr)	Negative	K28.5 D17.4 D31.7 D31.7
Open selective replicate	(OPNyr)	Negative	K28.5 D17.4 AL_PD D31.7

The Ordered Set definitions of ARBx and OPNyy require the same valid AL_PA value in characters 3 and 4. (See 7.1.1 and 7.2.2.)

The Ordered Set definition of OPNyx require a valid AL_PA in characters 3 and 4. (See 7.2.1.)

The Ordered Set definition of OPNfr requires a D31.7 (hex 'FF' in both characters 3 and 4. The Ordered Set definition of OPNyr requires a valid AL_PA in character 3 and D31.7 (hex 'FF' in character 4. (See 7.3.1 and 7.3.2).

The Ordered Set definition of MRKtx requires a valid MK_TP and AL_PS in characters 3 and 4, respectively. (See 7.6.)

Table 3 — Primitive Sequences

Primitive Sequence		Beginning RD	Ordered Set
Loop Initialization--F7,F7	(LIP)	Negative	K28.5 D21.0 D23.7 D23.7
Loop Initialization--F8,F7	(LIP)	Negative	K28.5 D21.0 D24.7 D23.7
Loop Initialization--F7,x	(LIP)	Negative	K28.5 D21.0 D23.7 AL_PS
Loop Initialization--F8,x	(LIP)	Negative	K28.5 D21.0 D24.7 AL_PS
Loop Initialization--reset	(LIPyx)	Negative	K28.5 D21.0 AL_PD AL_PS
Loop Port Enable	(LPEyx)	Negative	K28.5 D5.0 AL_PD AL_PS
Loop Port Enable all	(LPEfx)	Negative	K28.5 D5.0 D31.7 AL_PS
Loop Port Bypass	(LPByx)	Negative	K28.5 D9.0 AL_PD AL_PS
Loop Port Bypass all	(LPBfx)	Negative	K28.5 D9.0 D31.7 AL_PS

The Ordered Set definition of LIP includes two flags (F7 and F8) to identify the reason for the LIP. AL_PS is used to identify the L_Port that initiate the LIP; AL_PD is used to identify the L_Port that should be reset (See 7.7)

The Ordered Set definitions of LPEyx and LPByx require a valid AL_PA in characters 3 and 4. Note: LPEfx and LPBfx use D31.7 (hex 'FF') to indicate that it shall be processed by "all" L_Ports. (See 7.8.)

7 FC-AL Primitive Signals and Sequences

The Arbitrate and Mark Primitive Signals may be transmitted in place of an Idle and therefore, may be removed for clock skew management. All other Primitive Signals defined in this standard shall follow the FC-PH rule for transmitting R_RDYs (i.e., two (2) Fill Words shall precede and follow these Primitive Signals with at least six (6) Primitive Signals between frames). (See ANSI X3.230, FC-PH, 16.3.2 and clause 6 for a specification of the following Ordered Sets.)

7.1 Arbitrate Primitive Signals (ARB)

7.1.1 Arbitrate (ARBx)

Arbitrate (ARBx) is transmitted on a Loop by a participating L_Port to request access to the Loop. Each ARBx shall contain the AL_PA (x value) of the L_Port making the request.

7.1.2 Arbitrate (ARB(F0))

Arbitrate (ARB(F0)) is transmitted on a Loop to manage access fairness. Since this is a low-priority ARB, any arbitrating L_Port may replace the ARB(F0) with its ARBx. ARB(F0) is also used while selecting a temporary Loop master during Loop initialization.

7.1.3 Arbitrate (ARB(F7))

Arbitrate (ARB(F7) is transmitted on a Loop by an L_Port which does not have a valid AL_PA. This arbitration character is used to quiesce the Loop prior to transmitting a LIP when initializing to obtain a valid AL_PA. Since this is a low-priority ARB, any arbitrating L_Port may replace the ARB(F7) with its ARBx, thereby forcing the initializing L_Port to the end of the fairness window. The L_Port shall treat the ARB(F7) as a higher priority arbitration character than ARB(F0) (i.e., any ARB(F0) shall be replaced by ARB(F7)).

7.2 Open Primitive Signals (OPNy)

An originating L_Port determines the AL_PD (y value) of OPNy by checking the D_ID of the frame. If the left-most two bytes of the D_ID are the same as the left-most two bytes of the native address identifier of the originating L_Port or the left-most two bytes of the D_ID are hex '0000', then the AL_PD shall be the right most byte of the D_ID. Otherwise, the AL_PD shall be hex '00' (the FL_Port); the D_ID is addressed to the Fabric or to a Port not on the same Loop.

7.2.1 Open full-duplex (OPNyx)

Open full-duplex (OPNyx) is transmitted on a Loop by a participating L_Port to indicate that it is ready for Data and Link_Control frame transmission and reception (i.e., full-duplex). (See ANSI X3.230, FC-PH, 4.6, model 2.) The OPNyx shall contain the AL_PD (destination – y value) of the L_Port to be opened and the AL_PS (source – x value) of the L_Port which transmitted OPNyx.

OPNyx that is RECeived by an L_Port in the correct state indicates that another participating L_Port desires to communicate in full-duplex mode with the L_Port that received OPNyx.

7.2.2 Open half-duplex (OPNyy)

Open half-duplex (OPNyy) is transmitted on a Loop by a participating L_Port to indicate that it is ready for Data and Link_Control frame transmission and Link_Control frame reception (i.e., half-duplex). (See ANSI X3.230, FC-PH, 4.6, model 1.) The OPNyy shall contain the AL_PD (destination – y value) of the L_Port to be opened.

OPNyy that is received by an L_Port in the correct state indicates that another participating L_Port desires to communicate in half-duplex mode with the L_Port that received OPNyy. The opened L_Port shall not transmit Data frames.

7.3 Open Replicate Primitive Signals (OPNr)

Open Replicate (OPNr) is transmitted on a Loop by a participating L_Port which desires to communicate with a group of NL_Ports on the same Loop. The requesting L_Port has won arbitration and is in the OPEN state. Transmitted frames shall be Class 3, although no buffer-to-buffer flow control (R_RDY) is used. If R_RDYs are transmitted by the L_Port in the OPEN state, they shall be ignored. Frame reception is not guaranteed at each designated NL_Port (i.e., D_ID of the frame header may not be recognized by FC-2 or receive buffers may not be available). To avoid overflowing buffers and to assure that all designated NL_Ports can receive each replicate frame, the requesting L_Port should limit the number and size of frames that it transmits. The L_Port in the OPEN state shall discard all received frames.

NOTE — Although an FL_Port does not replicate frames through the Fabric, an FL_Port may transmit OPNr to communicate with multiple NL_Ports.

When an L_Port is in the MONITORING or ARBITRATING state and recognizes OPNr (where the AL_PD is either hex 'FF' or the AL_PA of the NL_Port), it shall set REPLICATE to TRUE(1). While REPLICATE is TRUE(1), each frame shall be retransmitted to the next L_Port on the Loop. NL_Ports shall provide all frames to FC-2 for further processing, however, the FL_Port shall not propagate any frame through the Fabric.

NOTE — Restricting the FL_Port prevents duplicate frames from being delivered to an NL_Port on the same Loop as the originator of the OPNr from a broadcast or multicast server in the Fabric.

When CLS is received, all L_Ports with REPLICATE set to TRUE(1), shall set REPLICATE to FALSE(0).

If an L_Port wins arbitration while REPLICATE is TRUE(1) (e.g., the L_Port which originated the OPNr was removed from the Loop before transmitting CLS), the L_Port in the Arbitration Won state shall transmit CLS (i.e., causes all L_Ports to set REPLICATE to FALSE(0)) and shall go to the TRANSFER state. (See 8.4.3, item 15 and table 6.)

7.3.1 Open broadcast replicate (OPNfr)

Open broadcast replicate (OPNfr where f and r = hex 'FF') is transmitted on a Loop by a participating L_Port which desires to communicate with all participating NL_Ports on the Loop.

7.3.2 Open selective replicate (OPNyr)

Open selective replicate (OPNyr where y = AL_PD and r = hex 'FF') is transmitted on a Loop by a participating L_Port which desires to communicate with a subset of NL_Ports on the Loop. The requesting L_Port shall transmit OPNyr (where y is a member of the subset) to each NL_Port in the subset group. OPNyr may be transmitted to group members in any order. (See annex L.)

NOTE — The following sequence of events is a valid example and shows some of the versatility of using OPNyr.

Arbitrate and win
Transmit OPN(17,FF), transmit frame (17 processes)
Transmit OPN(23,FF), transmit frame (17 and 23 process)
Transmit OPN(76,FF), transmit frame (17, 23, and 76 process)
CLS

7.4 Close Primitive Signal (CLS)

Close (CLS) is transmitted on a Loop by a participating L_Port. Once an L_Port has transmitted CLS, the L_Port shall not transmit frames or R_RDYs in the current circuit. CLS indicates that the transmitting L_Port is prepared to or has relinquished control of the Loop for the current circuit. (See 8.4.)

7.5 Dynamic Half-Duplex Primitive Signal (DHD)

Dynamic Half-Duplex (DHD) is transmitted on a Loop by the L_Port in the OPEN state (in lieu of CLS) to indicate to the L_Port in the OPENED state that it has no more Data frames to transmit. DHD shall only be transmitted if the L_Port in the OPENED state has indicated via Login, support of the DHD feature. The DHD supported login bit is found in FC-PH-3 (see ANSI X3.303-199x, FC-PH-3, 23.6.2.3). DHD allows L_Ports to make more efficient use of the established circuit (see annex B) by:

1. allowing an L_Port which is only capable of half-duplex data transfers, to transfer Data frames in the opposite direction without re-arbitrating.

2. allowing an L_Port which is in the OPENED state to transmit all Data frames, even though the L_Port in the OPEN state has finished its data transfer.

Transmitting DHD only affects Data frames (i.e., Link_Control frames and R_RDYs may still be transmitted) just as in the definition of an OPNyy (half-duplex open). (See 7.2.2.) The recipient of DHD shall transmit CLS when it has finished its transmissions.

NOTE — DHD does not prohibit, either L_Port from transmitting the first CLS. However, barring unusual circumstances, an L_Port in the OPEN state would normally not transmit CLS, if it has transmitted DHD.

7.6 Mark Primitive Signal (MRKtx)

Mark (MRKtx) is transmitted on a Loop by a master control point to synchronize other Nodes. (See annex H.) The L_Port shall request to transmit MRKtx at the appropriate time (REQ(mark as tx)) and the LPSM shall attempt to transmit one MRKtx for this request. Since MRKtx shall only replace a Fill Word, it is possible that the mark window is exceeded (i.e., REQ(mark as tx) is withdrawn) before the MRKtx can be transmitted (i.e., no MRKtx is transmitted).

The type of synchronization (MK_TP) is expressed in character 3; the AL_PA of the originator of the MRKtx is in character 4 (x value). MK_TP is vendor unique and the interpretation and use is beyond the scope of this standard. The value(s) shall be assigned from the neutral disparity characters in table 1.

When MRKtx is received by the originator (i.e., x = AL_PS), the MRKtx shall be replaced with the current Fill Word. All other L_Ports which are in the MONITORING, ARBITRATING, XMITTED CLOSE, or TRANSFER state shall retransmit the received MRKtx.

NOTE — Since not all states retransmit MRKtx, in order to guarantee that all L_Ports receive MRKtx, the originator has to be in the OPEN state and no other L_Ports in the OPENED state (i.e., all other L_Ports are either in the MONITORING or ARBITRATING state).

7.7 Loop Port Bypass/Enable Primitive Sequences

The Loop Port Bypass and Loop Port Enable Primitive Sequences are used to control access of an L_Port to the Loop as well as the Bypass Circuit (if present). The Bypass Circuit may be used to physically bypass an L_Port, however, the L_Port is also logically bypassed (i.e., the L_Port cannot originate Transmission Words on the Loop). (See 8.1.4 and annex I.)

7.7.1 Loop Port Bypass (LPByx)

Loop Port Bypass (LPByx) is transmitted on a Loop to set the Bypass Circuit (if present) and to bypass an L_Port. The originator of the LPByx (as identified by AL_PS in character 4 – x value) may be a diagnostic manager or an operating L_Port that has determined that a "defective" L_Port (identified by AL_PD in character 3 – y value) exists on the Loop.

When LPByx is recognized and the Bypass Circuit (if present) has been set, the L_Port shall not originate Transmission words (except for clock skew). The L_Port shall only monitor the Loop (as in non-participating mode), but shall keep its AL_PA until it recognizes LIP. When LIP is received, the L_Port shall assume that its AL_PA is being used by another L_Port and it shall enter the non-participating mode. LPByx is primarily used to diagnose the Bypass Circuit and for error recovery. (See annex I.)

Each L_Port in the MONITORING, ARBITRATING, INITIALIZING, or OPEN-INIT state shall retransmit the received LPByx. When LPByx is received by the originator (i.e., x = AL_PA), the LPByx shall be replaced with the current Fill Word.

Although LPByx may be transmitted in a number of states, not all states retransmit LPByx. To guarantee that the designated L_Port (as identified by the y value) receives LPByx, the originator shall be in the OPEN state and all other L_Ports shall be in the MONITORING or ARBITRATING state or all L_Ports shall be in the OPEN-INIT state.

Once an L_Port is bypassed and the Bypass Circuit (if present) has been set, the L_Port shall only monitor the Loop for a LPEyx (where y = AL_PA) or LPEfx and LIP. LIP is only used as a signal to relinquish its AL_PA; the L_Port shall not go to the OPEN-INIT state.

7.7.2 Loop Port Bypass all (LPBfx)

Loop Port Bypass all (LPBfx where f = hex 'FF') is transmitted on a Loop to set all Bypass Circuit(s) (if present) except for the L_Port at x. The originator of the LPBfx is identified by the AL_PS in character 4 (x value). The main purposed of this primitive is to verify that an operating Loop is possible, however, it is also useful to bypass a non-participating L_Port (i.e., the L_Port does not have an AL_PA).

When LPBfx is recognized, all L_Ports on the Loop (participating or non-participating), shall set the Bypass Circuit (if present). (See annex I.)

Each L_Port in the MONITORING, ARBITRATING, INITIALIZING, or OPEN-INIT state shall retransmit the received LPBfx. When LPBfx is received by the originator (i.e., x = AL_PA), the LPBfx shall be replaced with the current Fill Word.

Although LPBfx may be transmitted at any time, not all states retransmit LPBfx. To guarantee that all L_Ports receive LPBfx, the originator shall be in the OPEN state and all other L_Ports shall be in the MONITORING or ARBITRATING state or all L_Ports shall be in the OPEN-INIT state.

7.7.3 Loop Port Enable (LPEyx)

Loop Port Enable (LPEyx) is transmitted on a Loop to reset the Bypass Circuit (if present) and to enable an L_Port that had been previously bypassed without an intervening LIP being received. The destination L_Port is identified by the AL_PD in character 3 (y value). The originator of the LPEyx is identified by the AL_PS in character 4 (x value).

When LPEyx is recognized, the previously bypassed L_Port may participate on the Loop (e.g., originate frames). LPEyx is primarily used to detect if a Bypass Circuit is present and operational and for error recovery. (See annex I.)

Each L_Port in the MONITORING, ARBITRATING, INITIALIZING, or OPEN-INIT state shall retransmit the received LPEyx. When LPEyx is received by the originator (i.e., x = AL_PA), the LPEyx shall be replaced with the current Fill Word.

Although LPEyx may be transmitted at any time, not all states retransmit LPEyx. To guarantee that the designated L_Port (as identified by the y value) receives LPEyx, the originator shall be in the OPEN state and all other L_Ports shall be in the MONITORING or ARBITRATING state or all L_Ports shall be in the OPEN-INIT state.

7.7.4 Loop Port Enable all (LPEfx)

Loop Port Enable all (LPEfx where f = hex 'FF') is transmitted on a Loop to reset all Bypass Circuit(s) (if present) that may have been previously set and to enable all L_Ports to participate on the Loop (e.g., originate frames). The originator of the LPEfx is identified by the AL_PS in character 4 (x value). When an L_Port has been bypassed, it may have lost its AL_PA (e.g., the L_Port is required to relinquish its AL_PA upon recognizing a LIP). Therefore, LPEfx is very useful to allow these L_Ports (which no longer have an AL_PA) to be enabled on the Loop.

When LPEfx is recognized, a previously bypassed participating L_Port may participate on the Loop; a previously non-participating L_Port may perform Loop Initialization. LPEfx is primarily used to detect if a Bypass Circuit is present and operational and for error recovery. (See annex I.)

Each L_Port in the MONITORING, ARBITRATING, INITIALIZING, or OPEN-INIT state shall retransmit the received LPEfx. When LPEfx is received by the originator (i.e., x = AL_PA), the LPEfx shall be replaced with the current Fill Word.

Although LPEfx may be transmitted at any time, not all states retransmit LPEfx. To guarantee that all L_Ports receive LPEfx, the originator shall be in the OPEN state and all other L_Ports shall be in the MONITORING or ARBITRATING state or all L_Ports shall be in the OPEN-INIT state.

7.8 Loop Initialization Primitive Sequences (LIP)

Loop Initialization (LIP) is a Primitive Sequence used by an L_Port to detect if it is part of a Loop or to recover from certain Loop errors. (See 8.4.3, items 21, 22, and 23 and clause 10.)

The LIP carries with it information on why the LIP was transmitted in the right-most two characters. Other L_Ports may make decisions based on this information (e.g., inform an operator of a Loop failure).

7.8.1 Loop Initialization — no valid AL_PA

Loop Initialization (LIP(F7,F7)) is used by the originating L_Port to acquire an AL_PA.

7.8.2 Loop Initialization — Loop failure; no valid AL_PA

Loop Initialization (LIP(F8,F7)) is used by the originating L_Port to indicate that a Loop failure has been detected at its receiver. The L_Port has not completed initialization or is bypassed, therefore, the hex 'F7' is used instead of a valid AL_PA.

7.8.3 Loop Initialization — valid AL_PA

Loop Initialization (LIP(F7,AL_PS)) is used by the originating L_Port (identified by AL_PS) to reinitialize the Loop. The L_Port may have noticed a performance degradation (e.g., it has been arbitrating longer than it deemed reasonable) and is trying to restore the Loop into a known state.

7.8.4 Loop Initialization — Loop failure; valid AL_PA

Loop Initialization (LIP(F8,AL_PS)) is used by the originating L_Port (identified by AL_PS) to indicate that a Loop failure has been detected at its receiver.

7.8.5 Loop Initialization — reset L_Port

Loop Initialization (LIP(AL_PD,AL_PS)) is used by the originating L_Port (identified by AL_PS) to reset the NL_Port (identified by AL_PD). All L_Ports shall treat this LIP as specified in 7.8.3, however, the NL_Port at AL_PD may also perform a vendor

specific reset. If AL_PD = hex 'FF', a vendor specific reset shall be performed by all L_Ports (except the one at AL_PS). All L_Ports (including those which do not have an AL_PA), shall treat this as an L_Port reset.

8 L_Port operation

To simplify L_Port design and minimize Transmission Word propagation delay, the following general rules apply:

— all routing decisions by the LPSM (except during initialization) shall be made based on the AL_PA in the Primitive Signals (i.e., during normal operation, no LPSM routing decisions are made based on frame content);

— there is no requirement for logging errors that are detected when retransmitting Transmission Words; and,

— frame detection shall not be supported in the ARBITRATING and MONITORING states unless REPLICATE is set to TRUE(1) (see 7.3).

The maximum delay of a Transmission Word through an L_Port in the MONITORING or ARBITRATING state shall not exceed six (6) Transmission Word periods.

The following steps show an example for an L_Port to transfer one or more ANSI X3.230, FC-PH frames on a Loop:

(1) The L_Port requests the LPSM to obtain access to the Loop.

(2) The LPSM transmits ARBx continuously until a matching ARBx is received. When ARBx is received, the L_Port opens the Loop (i.e., stops retransmitting received Transmission Words).

(3) The LPSM transmits OPNy to establish a point-to-point circuit on the Loop. OPNy may be followed by ANSI X3.230, FC-PH frame(s). The number of frames that can immediately be transmitted is based on BB_Credit. (See 8.3.6).

(4) Either L_Port may transmit a CLS when it finishes transmitting frames. The receiving L_Port completes transmitting its frame(s), retransmits the CLS, and closes its end of the Loop. When the CLS returns to the L_Port which originated the CLS, this L_Port closes its end of the Loop.

NOTE — Since either open L_Port may begin a close, an L_Port must be prepared to handle a CLS simultaneously with or on the next Transmission Word after entering the XMITTED CLOSE state.

8.1 History variables

8.1.1 Access fairness history

The access fairness algorithm requires three memory elements that shall be maintained and used by each L_Port:

(1) **ACCESS** — the value of this variable is used by an L_Port to decide whether to use the fairness algorithm. (See 8.4 for management requirements of ACCESS);

(2) **ARB_WON** — the value of this variable is used by an L_Port to identify the L_Port which won arbitration. (See 8.4 for management requirements of ARB_WON.)

(3) **ARB_PEND** — the value of this variable is used by an L_Port with AL_PA = x to remember that it has transmitted one or more ARBx Primitive Signals. (See 8.4 for management requirements of ARB_PEND.)

8.1.2 Duplex mode history

The OPENED state requires one memory element, called DUPLEX, to determine how the L_Port was opened. If DUPLEX is FALSE(0), the circuit is operating in half-duplex mode; if DUPLEX is TRUE(1), the circuit is operating in full-duplex mode. (See 8.4 for management requirements of DUPLEX.)

8.1.3 Replicate mode history

The MONITORING and ARBITRATING states require one memory element, called REPLICATE, to remember if an OPNr had been received. If REPLICATE is FALSE(0), the states operate normally; if REPLICATE is TRUE(1), all Transmission Words are received and retransmitted and all frames are provided to FC-2 for further processing. (See 7.3 and 8.4.3, items 13 and 14.)

The OPEN state requires REPLICATE to remember that OPNr was transmitted in the ARBITRATION WON state. If REPLICATE is FALSE(0), the state operates normally; if REPLICATE is TRUE(1), the L_Port shall discard all received frames. (See 7.3 and 8.4.3, items 15 and 16.)

The ARBITRATION WON state requires REPLICATE to detect that the originator of the OPNr left the circuit without transmitting a CLS. (See 7.3 and 8.4.3, item 15.)

8.1.4 L_Port bypassed history

The MONITORING state requires one memory element, called LP_BYPASS, to determine whether the L_Port may originate Transmission Words on the Loop (e.g., ARBx, OPNy, frames, etc.). When LP_BYPASS is FALSE(0), the L_Port is "enabled"; if LP_BYPASS is TRUE(1), the L_Port is "bypassed."

An L_Port is bypassed when it recognizes LPByx (where y is the AL_PA of the L_Port), LPBfx, or at the request of the L_Port (REQ(bypass L_Port)). When an L_Port is bypassed, it shall set the Bypass Circuit (if present) and shall set LP_BYPASS to TRUE(1). If an L_Port recognizes LIP while LP_BYPASS is TRUE(1), the L_Port shall relinquish its AL_PA and shall enter the non-participating mode.

An L_Port is enabled when it recognizes LPEyx (where y is the AL_PA of the L_Port), LPEfx, or at the request of the L_Port (REQ(enable L_Port)). When an L_Port is enabled, it shall reset the Bypass Circuit (if present) and shall set LP_BYPASS to FALSE(0). When an L_Port is enabled, the L_Port shall operate normally (i.e., it shall be in the non-participating or participating mode, depending on whether it has a valid AL_PA). (See 8.3.1 and 8.4.3, item 13.)

8.1.5 DHD received history

The OPENED states requires one memory element, called DHD_RCV. This variable is set to TRUE(1) if DHD is received. The variable is checked when the L_Port in the OPENED state has completed all transmissions to the L_Port in the OPEN state. If DHD_RCV is FALSE(0), then the L_Port may continue to wait to receive CLS (normal operation) or it may transmit CLS. If DHD_RCV is TRUE(1), then the L_Port shall transmit CLS. (See annex B.)

8.2 Timeouts

8.2.1 FC-PH timeout values

Timeout values and related timeout procedures in ANSI X3.230, FC-PH, 29.2, shall be used.

8.2.2 Arbitrated Loop timeout value

The Arbitrated Loop timeout (AL_TIME) is specified as 15 ms (-0%+20%), which represents two times the worst case round-trip latency for a very large Loop. AL_TIME is based on twice the sum of the following values:

— 134 times an L_Port internal latency of six (6) Transmission Word periods at the implemented data rate of the L_Port and

— 134 times 10 km, the cable latency (3,5 ns/meter for electrical; 5 ns/meter for optical).

NOTE — It is conceivable that the maximum round-trip delay of a loop configuration is greater than two (2) times the minimum AL_TIME. However, determining interoperability when using a different AL_TIME values is outside the scope of this standard.

8.3 Operational characteristics

8.3.1 Modes of operation

An L_Port is in one of two operational modes:

participating mode: An L_Port is in participating mode when it has acquired an AL_PA (e.g., through the initialization process. See clause 10.) Since there is no enforceable limit to the number of L_Ports that may be physically connected to a Loop, a maximum of 127 L_Ports (1 FL_Port and 126 NL_Ports) shall be in participating mode on the same Loop at the same time.

NOTE — Some laser safety requirements may further limit the number of L_Ports that may be connected in a Loop because of propagation delays.

An L_Port that is in participating mode may voluntarily relinquish control of its AL_PA and enter non-participating mode. This allows another L_Port to reuse that AL_PA.

non-participating mode: An L_Port is in non-participating mode when it does not have a valid AL_PA. Reasons for not having an AL_PA are: the L_Port was unable to obtain an AL_PA; the L_Port voluntarily does not participate, or the L_Port has been bypassed and has recognized a LIP. Non-participating mode is the default operational mode for an L_Port. An L_Port in non-participating mode shall not arbitrate for access to and shall not respond to any ARBx, OPNy, or OPNr received on the Loop. (See 8.4.3 MONITORING.)

NOTE — A non-participating L_Port does not have a valid AL_PA and can therefore not be bypassed (if a Bypass Circuit is present) by another L_Port. To prevent a non-participating L_Port from causing a Loop failure, it is recommended that a non-participating L_Port requests a bypass (REQ(bypass L_Port)).

8.3.2 Invalid Transmission Word processing

An L_Port is capable of retransmitting valid Transmission Words and making substitutions for invalid Transmission Words (see 8.4):

— when the L_Port is in the MONITORING or ARBITRATING state and

- an invalid Transmission Character or a misplaced Special Character is detected, the L_Port shall substitute any valid Transmission Character (see ANSI X3.230, FC-PH, clause 17) or

- if an invalid Beginning Running Disparity condition is detected on an Ordered Set, the L_Port shall substitute the current Fill Word.

— when the L_Port is in any other state (see ANSI X3.230, FC-PH, 24.3.5, and clause 29).

8.3.3 Clock skew management

For clock skew management (i.e., frequency offset), when processing Transmission Words between frames, any ARBx shall be treated the same as Idle. Fill Words or any Ordered Set defined for use as a Primitive Sequence shall be treated equally. (See clause 7 and ANSI X3.230, FC-PH, clause 17.) If an L_Port is required to remove one of these Transmission Words, the L_Port shall transmit at least two of these Transmission Words before removing the next one of these Transmission Words. (See annex G.)

NOTE — Although two Fill Words are transmitted between R_RDYs, an L_Port is not guaranteed to receive two Fill Words between each R_RDY. (See ANSI X3.230, FC-PH, 16.3.2.)

If it becomes necessary to add a Fill Word for clock skew management, the L_Port shall normally transmit the current Fill Word. However, if the last received Transmission Word is LR or LRR (which is used during certain ANSI X3.230, FC-PH, 16.4 Primitive Sequences), LR or LRR shall be transmitted, respectively. See each state in 8.4 for the procedure to determine the current Fill Word.

NOTE — Because of clock skew management, when 8.4.3 and clause 9 mention that the current Fill Word is to be transmitted, it may not actually be transmitted (i.e., it may be absorbed by the clock skew management circuit).

8.3.4 Primitive Signal and Sequence substitution

An L_Port shall be capable of FC-AL Primitive Signal substitution:

— when an L_Port is in the MONITORING or ARBITRATING state, FC-AL Primitive Signal substitution shall be used as specified in each state in 8.4 or

— when an L_Port is in any other state, FC-AL Primitive Signals are either processed or discarded by the L_Port as specified in each state in 8.4.

LIP, LPE, and LPB processing is specified independently in each state in 8.4.

8.3.5 Error detection and recovery

Each state in 8.4 contains the procedures for handling failures. State transitions are considered to take place instantaneously and no error detection takes place during a state transition. Any failure or subsequent state request that occurs during a state transition shall be detected in the subsequent state.

Following recovery from a failure, the L_Port shall comply with the provisions for Sequence integrity, error detection, and Sequence recovery specified in ANSI X3.230, FC-PH, 24.3.5 and clause 29.

8.3.6 BB_Credit and Available_BB_Credit

BB_Credit and Available_BB_Credit are used when transmitting a SOFc1, a Class 2, or a Class 3 frame. Before Login, the "Alternate BB_Credit Management" bit and BB_Credit shall be set to *0* and one (1) in the OLD-PORT state and to *1* and zero (0) in the OPEN-INIT state, respectively. (See 8.4.3, and items 22 and 23). During Login, BB_Credit shall be set to a value that represents the number of receive buffers that an L_Port shall guarantee to have available when a communication path (i.e., a circuit) is established.

When on a Loop, L_Ports have unique characteristics (unlike point-to-point or Fabric-attached N_Ports):

— communication paths are dynamic;

— an L_Port may have frames in the receive buffers from the previous communication when a new communications path is established. Even a BB_Credit equal to one (1) may overrun the receive buffers;

— using BB_Credit equal to zero (0) requires a turn-around delay and impedes performance at the beginning of each circuit; and,

— balancing BB_Credit at the end of a circuit may impede performance.

"Alternate BB_Credit Management" is used to achieve the best performance while addressing these unique Loop characteristics. To avoid a turn-around delay at the beginning of a circuit, L_Ports may take advantage of the BB_Credit Login value. Although balancing BB_Credit is not required (receive buffers may be emptied after the circuit is closed), the BB_Credit value represents the number of receive buffers that an L_Port is assumed to have available when the next circuit is established. Therefore, an L_Port shall not close a Loop unless the number of available receive buffers is at least equal to the largest BB_Credit Login value that the L_Port disseminated during Login.

A positive BB_Credit allows the opening L_Port to follow OPNy with frames, without waiting for an R_RDY. Once the number of R_RDYs discarded equals the number of frames that have been transmitted, Available_BB_Credit is used to transmit subsequent frames. Annex F provides an example of how these credits may be used.

NOTE — "Alternate BB_Credit Management" is written from the view of the L_Port that transmits the OPNy. The receiving L_Port may choose to identify the opening L_Port's BB_Credit, or immediately use Available_BB_Credit.

8.3.6.1 BB_Credit management per circuit

After transmitting OPNy, an L_Port may transmit one R_RDY for each free receive buffer before transmitting any frames. Since a minimum of six (6) Fill Words shall be transmitted between the OPNy and the first frame, if a receive buffer is available and the L_Port is ready to receive a frame from the L_Port that received the OPNy, at least one R_RDY shall be transmitted prior to the first frame. Subsequent R_RDYs may be transmitted to provide a balance between transmitting frames and transmitting R_RDYs.

After receiving OPNy, an L_Port shall transmit at least one R_RDY or the L_Port shall transmit CLS. CLS indicates that there are no free receive buffers or that the L_Port desires to close the circuit (i.e., has no frames to transmit).

The BB_Credit for each circuit is one of the following values:

— zero (0) (default value);

NOTE — If BB_Credit is zero (0), a Loop turn-around delay is required (i.e., an R_RDY must be received) before the opening L_Port is allowed to transmit the first frame.

— the minimum value of the BB_Credit of all L_Ports that are currently logged-in; or,

— the specific Login value of the other L_Port.

The L_Port may transmit the number of frames specified by BB_Credit. The L_Port shall discard one R_RDY for each of these frames sent. When the number of R_RDYs discarded equals the number of frames sent, the L_Port shall use Available_BB_Credit management.

8.3.6.2 Available_BB_Credit management per circuit

Once the L_Port has discarded the same number of R_RDYs as it has transmitted frames using the BB_Credit value, the L_Port shall use Available_BB_Credit for transmitting additional frames.

Available_BB_Credit is one of the following values:

— zero (0) – the initial value until an R_RDY is received; or.

— the number of R_RDYs received less the number of frames transmitted.

The L_Port may transmit the number of frames specified by Available_BB_Credit. For each frame sent, Available_BB_Credit is decremented by one (1); for each R_RDY received, Available_BB_Credit is incremented by one (1). As long as Available_BB_Credit is positive, the L_Port may transmit frames.

8.4 Loop Port State Machine (LPSM)

A Loop Port State Machine (LPSM) is used to define the behavior of the L_Ports when they require access to and use of a Loop. The following subclauses specify the state names, state diagram, and item references for the LPSM.

8.4.1 State names

The state names and numbers used in the LPSM, along with a brief description, are given below. Reference items for each state are considered part of each state. The reference item numbers are identified in the L_Port state machine diagram in 8.4.2. The reference item text follows the state machine diagram in 8.4.3.

MONITORING (0): The LPSM is transmitting received Transmission Words and if in the participating mode, monitoring the Loop for certain Ordered Sets (e.g., OPNy and OPNr). This is the default state of any L_Port.

ARBITRATING (1): The LPSM is arbitrating for control of the Loop.

ARBITRATION WON (2): The LPSM has received a matching ARBx (i.e., x = AL_PA of this L_Port) while arbitrating.

OPEN (3): The LPSM has transmitted OPNy while in the ARBITRATION WON state. Normal FC-2 protocol follows.

OPENED (4): The LPSM has received a matching OPNy (i.e., y = AL_PA of this L_Port) while in the MONITORING or ARBITRATING state. Normal FC-2 protocol follows.

XMITTED CLOSE (5): The LPSM has transmitted a CLS and intends to relinquish control of the Loop.

RECEIVED CLOSE (6): The LPSM has received a CLS.

TRANSFER (7): The LPSM, while in the OPEN state, has transmitted CLS and requires the Loop to communicate with another L_Port.

INITIALIZING (8): The LPSM is initializing or re-initializing.

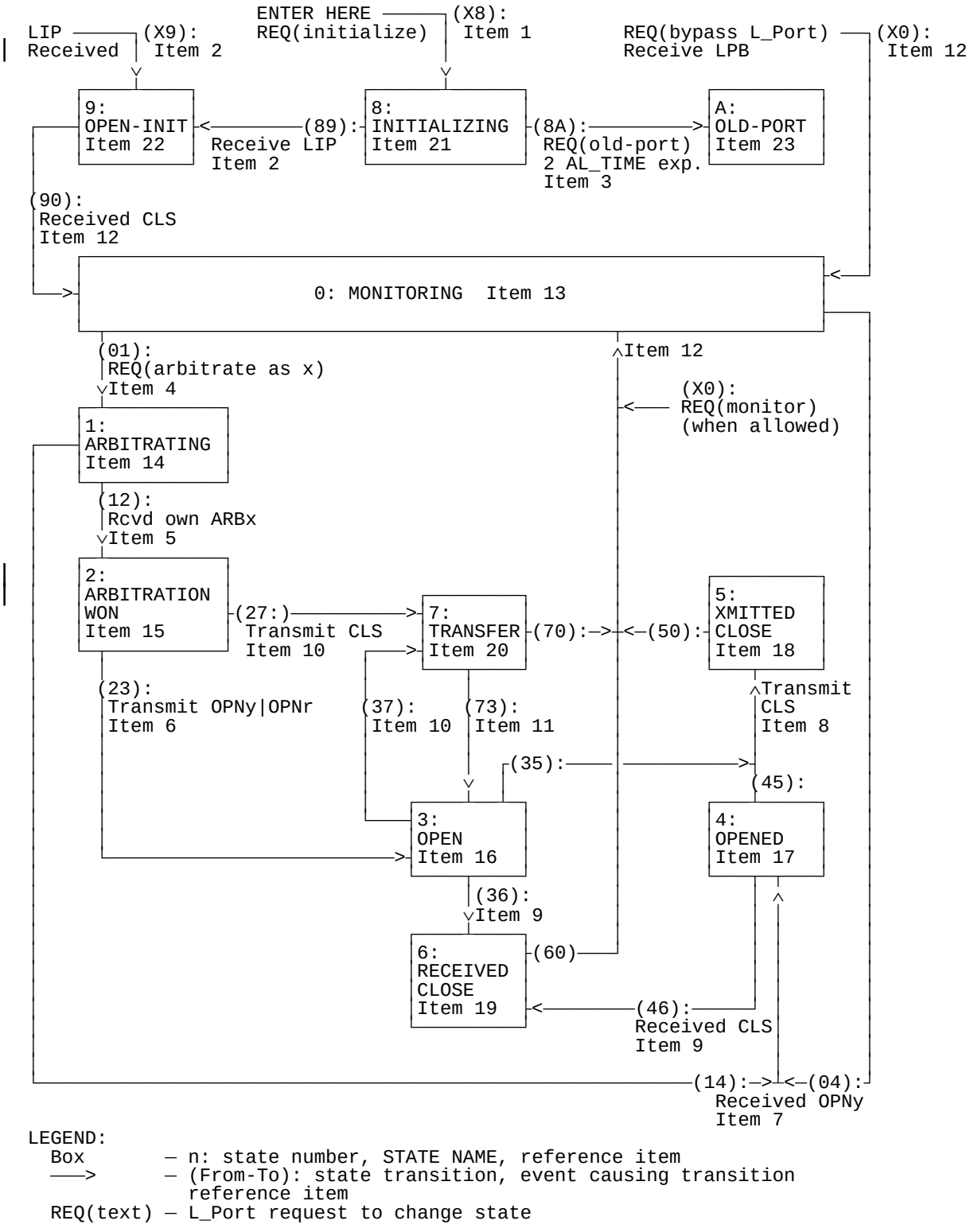
OPEN-INIT (9): The LPSM has recognized a LIP.

OLD-PORT (A): The LPSM has discovered that a non-L_Port is attached and the Arbitrated Loop protocol is not required.

8.4.2 State diagram

The state diagram is shown in figure 3. The numbered reference items for states and state transitions in 8.4.3 are normative parts of the LPSM definition. If the details were in the state diagrams, the diagrams would be difficult to read and interpret.

States are identified with a single letter or digit followed by a single colon character (e.g., 6:). Transitions identified as "(Xn):", where *n* is a single digit or letter, represent valid transitions from multiple states to the ending state, *n*, caused by an event outside the steady state operation of the LPSM. A transition identified as "(mn):", where *m* and *n* are single digits or letters, represents a transition from state *m* to state *n*. Each transition and state is accompanied by detailed specifications and requirements identified by the numbered reference item.



LEGEND:

Box	— n: state number, STATE NAME, reference item
——>	— (From-To): state transition, event causing transition reference item
REQ(text)	— L_Port request to change state

Figure 3 — State diagram

8.4.3 Reference items

This subclause is normative text for the LPSM. It is not intended to be read in order, rather it serves as normative notes identified on the state diagram.

Refer to this subclause when following the state machine. If detailed information is needed about a state or state transition, refer to the item number in the list below.

For conditions that are not explicitly listed in this section as causing state changes to occur, the LPSM shall remain in the current state. The text for each state below is supported by a detailed input/output table in clause 9.

1 **Transition (X8):** This transition shall be made at power-on of an L_Port, after detecting a failure (see clause 10 and ANSI X3.230, FC-PH, clause 23), or from any state when the L_Port requests it. (See item 21.)

All fibre-type dependent operations shall be complete before making this transition (e.g., Open Fibre Control). (See ANSI X3.230, FC-PH, clauses 5 to 10.)

2 **Transitions (X9):, (89):** The LPSM shall make the transition to the OPEN-INIT state. (See items 13, 14, 16, 17, 18, 19, 20, 21, 22, and 23.)

3 **Transition (8A):** The LPSM shall make the transition to the OLD-PORT state. (See items 21 and 23.)

4 **Transition (01):** The LPSM shall make the transition to the ARBITRATING state. (See items 13 and 14.)

5 **Transition (12):** The LPSM shall make the transition to the ARBITRATION WON state. (See items 14 and 15.)

6 **Transition (23):** The LPSM shall make the transition to the OPEN state. (See items 15 and 16.)

7 **Transitions (04):, (14):** The LPSM shall make the transition to the OPENED state. (See items 13, 14 and 17.)

8 **Transitions (35):, (45):** The LPSM shall make the transition to the XMITTED CLOSE state. (See items 15, 16, 17 and 18.)

9 **Transitions (36):, (46):** The LPSM shall make the transition to the RECEIVED CLOSE state. (See items 16, 17 and 19.)

10 **Transition (27):, (37):** The LPSM shall make the transition to the TRANSFER state. (See items 15, 16, and 20.)

11 **Transition (73):** The LPSM shall make the transition to the OPEN state. (See items 16 and 20.)

12 **Transitions (X0):, (50):, (60):, (70):, (90):** The LPSM shall make the transition to the MONITORING state. (See items 13, 18, 20, and 22.)

13 **State 0 (MONITORING) actions:** The LPSM shall set DUPLEX to FALSE(0), ARB_WON to FALSE(0), and REPLICATE to FALSE(0). If the L_Port is in non-participating mode, the LPSM shall retransmit all received Transmission Words on the Loop. If the L_Port is in participating mode, the LPSM shall retransmit all received Transmission Words unless specifically stated otherwise. If the Bypass Circuit (if present) is set, the LPSM shall respond only to LPEyx (where y = the AL_PA of the L_Port) or LPEfx. If ARB_PEND is TRUE(1) and LP_BYPASS is FALSE(0), the L_Port shall make the transition to the ARBITRATING state. (See items 4 and 14.)

NOTE — ARB_PEND is set to TRUE(1) when an L_Port has transmitted one or more ARBx Primitive Signals (where x = AL_PA of the L_Port). The L_Port may have been opened by another L_Port while arbitrating. This flag forces the L_Port to finish arbitrating to assure that the fairness window is reset.

If Idle is received, the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If ARBx is received, the current Fill Word shall be modified as follows:

— if x = hex 'F0' and the current Fill Word is Idle, the current Fill Word shall not be changed;

— if x = hex 'F0' and the current Fill Word is not Idle, the current Fill Word shall be set to ARB(F0);

— if x <> AL_PA of the L_Port, the current Fill Word shall be set to ARBx; or,

— if x = AL_PA of the L_Port, the current Fill Word shall be changed to Idle.

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If the L_Port is in participating mode with LP_BYPASS set to FALSE(0):

— if REPLICATE is TRUE(1), the LPSM shall receive and retransmit all Transmission Words;

— if OPNfr is received, the LPSM shall set REPLICATE to TRUE(1) and retransmit the received OPNfr;

— if OPNyr is received where y = AL_PA of the L_Port, the LPSM shall set REPLICATE to TRUE(1) and retransmit the received OPNyr;

— if OPNy is received where y = AL_PA of the L_Port, the LPSM shall make the transition to the OPENED state. (See items 7 and 17);

— if any other OPNy is received, it shall be retransmitted;

— if ARBx is received:

- if x = AL_PA of the L_Port, the LPSM shall transmit the current Fill Word; the ARBx is discarded;
- if x = hex 'F0', the LPSM shall transmit the current Fill Word; or,
- if x <> AL_PA of the L_Port, the LPSM shall retransmit the ARBx.

— if MRKtx is received:

- if x = AL_PA of the L_Port, the LPSM shall transmit the current Fill Word; the MRKtx is discarded;
- if the MK_TP and AL_PS match the expected values, synchronization shall be performed; or,
- if x <> AL_PA of the L_Port, the received MRKtx shall be retransmitted.

— if CLS is received while REPLICATE is TRUE(1), the LPSM shall set REPLICATE to FALSE(0) and retransmit the received CLS; or,

— the LPSM shall make a transition to the ARBITRATING state when the L_Port requests arbitration (REQ(arbitrate as x)) and ACCESS is TRUE(1). (See items 4 and 14).

If LIP is received:

— if LP_BYPASS is FALSE(0), the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22); or,

— if LP_BYPASS is TRUE(1), the L_Port shall relinquish its AL_PA (i.e., go to the non-participating mode) and remain in the MONITORING state.

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present) and set LP_BYPASS to TRUE(1).

If LPEyx (y = AL_PA of the L_Port) or LPEfx is recognized or the L_Port requests to be enabled (REQ(enable L_Port)), the LPSM shall reset the Bypass Circuit (if present) and set LP_BYPASS to FALSE(0).

The LPSM shall retransmit all other received Transmission Words on the Loop. (See 8.3.2.)

Invalid Transmission Character substitution shall be performed as specified in 8.3.2; any other received Transmission Words shall be retransmitted on the Loop. (See 8.3.2.)

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests not to participate on the Loop (REQ(nonparticipat.)), the LPSM shall transmit at least 12 LIPs (with the right-most two characters equal to hex 'F7F7') to invoke Loop Initialization. This allows another L_Port to acquire the relinquished AL_PA. The 12 LIPs are only transmitted once for each REQ(nonpaticipat.) to allow this request to be active until the L_Port requests to participate (REQ(participating)). The L_Port shall not participate further in Loop Initialization until REQ(initialize) or REQ(participating) is set.

If the L_Port requests to participate on the Loop (REQ(participating)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 4 for complete input, output, and state transition rules.

14 **State 1 (ARBITRATING) actions:** The LPSM shall retransmit all received Transmission Words unless specifically stated otherwise. The LPSM shall transmit an ARBx (where x equals the AL_PA of the L_Port) when either an Idle or a lower priority ARBx is received. Once the LPSM has transmitted its own ARBx, it shall set ARB_PEND to TRUE(1) and shall not transmit a lower-priority ARBx.

If Idle is received, the current Fill Word shall be set to ARBx (where x equals the AL_PA of the L_Port). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If ARBx is received and x does not equal the AL_PA of the L_Port, the current Fill Word shall be modified as follows:

— if x = hex 'F0' and AL_PA = hex 'F7' (i.e., the L_Port is attempting to initialize), the current Fill Word shall be changed to ARB(F7);

— if x > AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port); or,

— if x < AL_PA, the current Fill Word shall be changed to the received ARBx.

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If ARBx is received and x equals the AL_PA of the L_Port, the LPSM shall make the transition to the ARBITRATION WON state. (See items 5 and 15.

If REPLICATE is TRUE(1), the LPSM shall receive all Transmission Words.

If OPNfr is received, the LPSM shall set REPLICATE to TRUE(1) and retransmit the received OPNfr.

If OPNyr is received where y = AL_PA of the L_Port, the LPSM shall set REPLICATE to TRUE(1) and retransmit the received OPNyr.

If OPNy is received where y = AL_PA of the L_Port, the LPSM shall make the transition to the OPENED state. (See items 7 and 17.)

If any other OPNy or OPNr is received, it shall be retransmitted.

If CLS is received and REPLICATE is TRUE(1), REPLICATE shall be set to FALSE(0). The CLS shall be retransmitted.

If MRKtx is received:

— if x = AL_PA of the L_Port, the LPSM shall transmit the current Fill Word; the MRKtx is discarded;

— if the MK_TP and AL_PS match the expected values, synchronization shall be performed; or,

— if x <> AL_PA of the L_Port, the received MRKtx shall be retransmitted.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.)

Invalid Transmission Character substitution shall be performed as specified in 8.3.2; any other received Transmission Words shall be retransmitted on the Loop. (See 8.3.2.)

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 5 for complete input, output, and state transition rules.

15 **State 2 (ARBITRATION WON) actions:** This is a transition state during which no Transmission Words are received. To identify this as the L_Port that won arbitration, the LPSM shall set ARB_WON to TRUE(1), ARB_PEND to FALSE(0), and the current Fill Word to ARB(F0). If the LPSM used AL_PA = hex 'F7' to win arbitration, it shall make the transition to the INITIALIZING state. If REPLICATE is TRUE(1), the L_Port shall transmit CLS and go to the TRANSFER state. (See items 10 and 20.) If the L_Port is using the fairness algorithm, ACCESS shall be set to FALSE(0); if the L_Port is not using the fairness algorithm, ACCESS shall be set to TRUE(1).

In this state, the L_Port shall make the decision to open the Loop or not to open the Loop:

— if the L_Port still requires access to the Loop (REQ(open yx), REQ(open yy), REQ(open fr), or REQ(open yr)), the LPSM shall transmit OPNy or the requested OPNr and shall make the transition to the OPEN state. (See items 6 and 16.) If OPNr is transmitted, REPLICATE shall be set to TRUE(1) or

— if the L_Port no longer needs access to the Loop (REQ(close)), the LPSM shall transmit OPNyy (where y = AL_PA of the L_Port) and shall make the transition to the OPEN state. (See items 6 and 16 and annex C.)

If the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

See table 6 for complete input, output, and state transition rules.

16 **State 3 (OPEN) actions:** The LPSM shall transmit at least six (6) current Fill Words; interspersed among these shall be one R_RDY for each frame that the L_Port is willing to receive. The L_Port shall process, and shall not retransmit subsequent Transmission Words received on its inbound fibre. The L_Port shall transmit Primitive Signals, Primitive Sequences, or frames as specified in ANSI X3.230, FC-PH. (See 8.3.6.)

If Idle is received, the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If ARB(F0) is received, the current Fill Word shall be set to Idle. Receiving ARB(F0) indicates that no other L_Port is now arbitrating (i.e., no L_Port changed ARB(F0) to ARBx).

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If CLS is received, the LPSM shall make the transition to the RECEIVED CLOSE state. (See items 9 and 19.)

If MRKtx is received where the MK_TP and AL_PS match the expected values, synchronization shall be performed. The received MRKtx shall not be retransmitted.

If REPLICATE is TRUE(1) and the L_Port requests a broadcast replicate (REQ(open fr) or another selective replicate REQ(open yr)), the LPSM shall transmit OPN(fr) or one OPN(yr) for each request at the next Fill Word, respectively.

If ACCESS is TRUE(1) and the L_Port requires communication with a different L_Port (REQ(transfer)), the LPSM shall transmit CLS instead of the next Fill Word and then shall make the transition to the TRANSFER state. (See items 10 and 20.) If ACCESS is FALSE(0), the request to transfer is ignored. If a Class 1 connection exists, the L_Port shall remove the Class 1 connection before transmitting a CLS; only the L_Port which received EOFdt shall transmit CLS.

The LPSM may begin to close the Loop (REQ(close)) by transmitting either CLS or DHD instead of the next Fill Word. If the login bit identifies that the L_Port in the OPENED state supports DHD, the LPSM may transmit DHD to indicate that it has finished transmitting Data frames. IF DHD is transmitted, the LPSM shall remain in the OPEN state, however, it shall not transmit Data frames. If CLS is transmitted, the LPSM shall make the transition to the XMITTED CLOSE state or the

TRANSFER state. If a Class 1 connection exists, the L_Port shall remove the Class 1 connection before transmitting a CLS; only the L_Port which received EOFdt shall transmit CLS. (See items 8 and 18 or 20.)

NOTE — Reasons for transmitting a CLS or DHD include, but are not limited to:

— ARBx was detected to indicate that another L_Port is arbitrating (the OPEN L_Port may close the Loop at a convenient time);
— there are no additional Sequences to transmit to the other L_Port; or,
— the L_Port is making the transition to the non-participating mode.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPB is recognized:

— if x = AL_PA of the L_Port, the received LPByx shall be discarded or

— if y = AL_PA of the L_Port or x'FF', the LPSM shall end the current transmission; set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.)

If REPLICATE is TRUE(1), all received Transmission Words (except CLS, MRKtx, and any Primitive Sequence) shall be discarded.

NOTE — This includes any frame(s) that traverses the Loop.

If the L_Port requests another L_Port to be either bypassed (REQ(bypass L_Port y)) or enabled (REQ(enable L_Port y) or REQ(enable all)), the LPSM shall begin to transmit LPB or LPE at the next Fill Word, until the Primitive Sequence is received.

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 7 for complete input, output, and state transition rules.

17 **State 4 (OPENED) actions:** The LPSM shall set ARB_WON to FALSE(0), REPLICATE shall be set to FALSE(0), and shall transmit the current Fill Word to replace the received OPNy. The L_Port shall transmit at least six (6) current Fill Words (interspersed among these shall be one R_RDY for each frame that the L_Port is willing to receive) before transmitting a CLS. The L_Port shall process, and shall not retransmit subsequent Transmission Words received on its inbound fibre. The L_Port shall transmit Primitive Signals, Primitive Sequences, or frames as specified in ANSI X3.230, FC-PH. (See 8.3.6.) If OPNyx was received, DUPLEX shall be set to TRUE(1); if OPNyy was received, DUPLEX shall be set to FALSE(0) and no Data frames shall be transmitted.

If this is a fair L_Port and ARB_PEND is TRUE(1), and if the x value of the OPNyx is equal to the AL_PA of the L_Port with which this NL_Port wished to communicate, and the LPSM was able to transmit frames to the other L_Port, then this NL_Port shall set ACCESS to FALSE(0) and ARB_PEND to FALSE(0); to indicate that it has met its arbitration requirement for the current access window.

If Idle is received and ARB_PEND is FALSE(0), the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If Idle is received and ARB_PEND is TRUE(1), the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port).

If ARBx is received and ARB_PEND is TRUE(1), the current Fill Word shall be modified as follows:

— if x > AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port);

— if x = AL_PA, the current Fill Word shall be changed to ARB(F0); or,

— if x < AL_PA, the current Fill Word shall be changed to the received ARBx.

If ARBx is received and ARB_PEND is FALSE(0), the current Fill Word shall be modified as follows:

— if x = AL_PA, the current Fill Word shall be changed to ARB(F0) or

— if x <> AL_PA, the current Fill Word shall be changed to the received ARBx.

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If OPNr or OPNy are received, they shall be discarded.

If DHD is received, the LPSM shall set DHD_RCV to TRUE(1). Receiving DHD is an indication to this L_Port that the LPSM in the OPEN state has no more Data frames to transmit. The L_Port shall respond to DHD by transmitting frames or CLS.

If DHD_RCV is TRUE(1) and the L_Port has completed all transfers (or it had nothing to transmit when it received DHD) to the L_Port in the OPEN state, it shall REQ(close) to begin closing the Loop. (See annex B.)

If CLS is received, the LPSM shall make the transition to the RECEIVED CLOSE state. (See items 9 and 19.)

If MRKtx is received where the MK_TP and AL_PS match the expected values, synchronization shall be performed. The received MRKtx shall not be retransmitted.

The LPSM may begin to close the Loop (REQ(close)) by transmitting CLS instead of the next Fill Word and then shall make the transition to the XMITTED CLOSE state. If a Class 1 connection exists, the L_Port shall remove the Class 1 connection before transmitting a CLS; only the L_Port which received EOFdt shall transmit CLS. (See items 8 and 18.)

NOTE — Reasons for transmitting CLS include, but are not limited to:

— ARBx has been detected to indicate that another L_Port is arbitrating (the OPENED L_Port may close the Loop at a convenient time);
— frame transmission is required with a different L_Port;
— there are no more Sequences to process with the other L_Port in this circuit; or,
— the L_Port is making the transition to the non-participating mode.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall end the current transmission; set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.)

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 8 for complete input, output, and state transition rules.

18 **State 5 (XMITTED CLOSE) actions:** The L_Port shall continue to operate on the Loop. The LPSM shall transmit only the current Fill Word (except MRKtx). The L_Port shall process, but shall not retransmit subsequent Transmission Words received on its inbound fibre (except MRKtx).

If Idle is received and ARB_PEND is FALSE(0), the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If Idle is received and ARB_PEND is TRUE(1), the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port).

If ARB(F0) is received and ARB_WON is TRUE(1), the current Fill Word shall be set to Idle. Receiving ARB(F0) indicates that no other L_Port is now arbitrating (i.e., no L_Port changed ARB(F0) to ARBx).

If ARB(F0) is received and ARB_WON is FALSE(0), the current Fill Word shall be modified as follows:

— if ARB_PEND is FALSE(0), the current Fill Word shall be changed to ARB(F0) or

— if ARB_PEND is TRUE(1), the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port).

If ARBx is received, ARB_WON is FALSE(0), and ARB_PEND is FALSE(0), the current Fill Word shall be modified as follows:

— if x = AL_PA of the L_Port, the current Fill Word shall be changed to ARB(F0)or

— if x <> AL_PA of the L_Port, the current Fill Word shall be set to ARBx.

If ARBx is received, ARB_WON is FALSE(0), and ARB_PEND is TRUE(1), the current Fill Word shall be modified as follows:

— if x > AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port);

— if x = AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port); or,

— if x < AL_PA, the current Fill Word shall be changed to the received ARBx.

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If CLS is received, the LPSM shall transmit the current Fill Word and shall make the transition to the MONITORING state. (See items 12 and 13.)

NOTE — If the L_Port had advertised a Login BB_Credit > 0, in order to avoid any overruns, it is advisable that the number of available buffers at least equal the Login BB_Credit before making the transition to the MONITORING state.

If MRKtx is received:

— if x = AL_PA of the L_Port, the LPSM shall transmit the current Fill Word; the MRKtx is discarded;

— if the MK_TP and AL_PS match the expected values, synchronization shall be performed; or,

— if x <> AL_PA of the L_Port, the received MRKtx shall be retransmitted.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.) If any other LPByx is received, it shall be replaced with the current Fill Word.

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 9 for complete input, output, and state transition rules.

19 **State 6 (RECEIVED CLOSE) actions:** The LPSM shall set REPLICATE to FALSE(0). The L_Port may continue to transmit frames until Available_BB_Credit or EE_Credit is exhausted. Any frame or R_RDY received from the other L_Port shall be discarded. The LPSM shall process, and shall not retransmit subsequent Transmission Words received on its inbound fibre. The L_Port shall transmit Primitive Signals, Primitive Sequences, or frames as specified in ANSI X3.230, FC-PH. When the LPSM transmits CLS (REQ(close)), the LPSM shall make the transition to the MONITORING state. (See items 12 and 13.)

NOTE — If the L_Port had advertised a Login BB_Credit > 0, in order to avoid any overruns, it is advisable that the number of available buffers at least equal the Login BB_Credit before making the transition to the MONITORING state.

If Idle is received and ARB_PEND is FALSE(0), the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If Idle is received and ARB_PEND is TRUE(1), the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port).

If ARB(F0) is received and ARB_WON is TRUE(1), the current Fill Word shall be set to Idle. Receiving ARB(F0) indicates that no other L_Port is now arbitrating (i.e., no L_Port changed ARB(F0) to ARBx).

If ARB(F0) is received and ARB_WON is FALSE(0), the current Fill Word shall be modified as follows:

— if ARB_PEND is FALSE(0), the current Fill Word shall be changed to ARB(F0) or

— if ARB_PEND is TRUE(1), the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port).

If ARBx is received, ARB_WON is FALSE(0), and ARB_PEND is FALSE(0), the current Fill Word shall be modified as follows:

— if x = AL_PA of the L_Port, the current Fill Word shall be changed to ARB(F0) or

— if x <> AL_PA of the L_Port, the current Fill Word shall be set to ARBx.

If ARBx is received, ARB_WON is FALSE(0), and ARB_PEND is TRUE(1), the current Fill Word shall be modified as follows:

— if x > AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port);

— if x = AL_PA, the current Fill Word shall be changed to ARBx (where x equals the AL_PA of the L_Port); or,

— if x < AL_PA, the current Fill Word shall be changed to the received ARBx.

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If MRKtx is received where the MK_TP and AL_PS match the expected values, synchronization shall be performed. The received MRKtx shall not be retransmitted.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall end the current transmission (e.g., frame); shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.)

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 10 for complete input, output, and state transition rules.

20 **State 7 (TRANSFER) actions:** The LPSM shall set REPLICATE to FALSE(0). The L_Port shall continue to operate on the Loop. The LPSM shall transmit only the current Fill Word (except MRKtx). The L_Port shall process, but shall not retransmit subsequent Transmission Words received on its inbound fibre (except MRKtx).

If Idle is received, the current Fill Word shall be set to Idle and ACCESS shall be set to TRUE(1). To assure that a single Idle is not discarded for clock skew by another L_Port, at least two Idles shall be transmitted before changing the current Fill Word to another value.

If ARB(F0) is received, the current Fill Word shall be set to Idle. Receiving ARB(F0) indicates that no other L_Port is now arbitrating (i.e., no L_Port changed ARB(F0) to ARBx).

If a Fill Word is to be transmitted, the current Fill Word shall be used.

If CLS is received:

— if the L_Port still requires access to the Loop (REQ(open yx) or REQ(open yy), the LPSM shall transmit OPNy to replace the received CLS and shall make the transition to the OPEN state. (See item 11 and 16);

— if the L_Port still requires access to the Loop (REQ(open fr) or REQ(open yr)), the LPSM shall transmit OPNr to replace the received CLS, shall set REPLICATE to TRUE(1), and shall make the transition to the OPEN state. (See item 11 and 16); or,

— if the L_Port no longer needs access to the Loop (REQ(monitor)), the LPSM shall make the transition to the MONITORING state. (See items 12 and 13.)

If MRKtx is received:

— if x = AL_PA of the L_Port, the LPSM shall transmit the current Fill Word; the MRKtx is discarded;

— if the MK_TP and AL_PS match the expected values, synchronization shall be performed; or,

— if x <> AL_PA of the L_Port, the received MRKtx shall be retransmitted.

If LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If LPByx (y = AL_PA of the L_Port) or LPBfx is recognized or the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.) If any other LPByx is received, it shall be replaced by the current Fill Word.

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

If the L_Port requests to transmit a MRKtx (REQ(mark as tx)), the LPSM shall transmit one MRKtx at the next appropriate Fill Word (see clause 7), unless REQ(mark as tx) is removed before MRKtx is transmitted.

See table 11 for complete input, output, and state transition rules.

21 **State 8 (INITIALIZING) actions:** The LPSM shall set LP_BYPASS to FALSE(0); shall transmit twelve (12) LIPs; and, shall not retransmit received Transmission Words except LPB and LPE. The L_Port shall continue to transmit LIP for up to two (2) maximum AL_TIMEs (see 7.8) and monitor only for LIP, LPB, and LPE.

During normal initialization the L_Port shall react as follows:

— if any LIP is recognized, the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22);

— if LPByx (y = AL_PA of the L_Port) or LPBfx is recognized, the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.) Any other LPByx shall be retransmitted;

— if LPEyx or LPEfx is recognized, the received LPE shall be retransmitted; or,

— if LIP, LPByx, or LPBfx has not been recognized within two (2) maximum AL_TIMEs, either there is a non-L_Port on the Loop or a Loop failure has been detected. If a non-L_Port is suspected, the L_Port shall go to the OLD-PORT state. (See items 3 and 23.) If a Loop failure is suspected, the L_Port shall attempt to recover the Loop by continuing in the INITIALIZING state and may use the procedure outlined in annex I.2.2 to bypass a failing L_Port.

During Loop recovery the L_Port shall react as follows:

— if LIP(y,x) is recognized and:

- y = hex 'F8', then the LPSM shall set the received LIP to LIP(F7,x) and shall make the transition to the OPEN-INIT state. (See items 2 and 22).

- y <> hex 'F8', the LPSM shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

— if LPByx is recognized, where x = AL_PA of the L_Port, the LBPyx shall be replaced by LIP. Since the transmitted LPByx was received, presumably, the Loop is operational. The L_Port shall reenter the INITIALIZING state.

— if LPByx (y = AL_PA of the L_Port) or LPBfx is recognized, the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.);

— if any other LPByx is received, it shall be retransmitted;

— if LPEyx or LPEfx is recognized, where x = AL_PA of the L_Port, the LPE shall be replaced by LIP. Since the transmitted LPE was received, presumably, the Loop is operational. The L_Port shall reenter the INITIALIZING state;

— if any other LPE is received, it shall be retransmitted; or,

— if the L_Port is unsuccessful in its attempt to recover the Loop (i.e., LIP or the transmitted LPB was not received during two (2) AL_TIMEs of each bypass attempt), the L_Port shall go to the OLD-PORT state. (See items 3 and 23.)

If at any time in the INITIALIZING state the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13.)

See table 12 for complete input, output, and state transition rules.

22 **State 9 (OPEN-INIT) actions:** The L_Port shall set ACCESS to TRUE(1), shall set the current Fill Word to Idle, shall set the "Alternate BB_Credit Management" bit to *1*, shall set BB_Credit to zero (0), shall transmit at least twelve (12) LIPs of the same type as the last LIP received, and shall continue with the initialization procedure by transmitting the LISM sequence as described in 10.4. During the LISM sequence transmission, the L_Port shall ignore all other Transmission Words.

During initialization only, two types of L_Ports are identified in the OPEN-INIT state:

(1) **Loop master:** This L_Port shall transmit and receive the Loop Initialization Sequences identified in 10.4.

(2) **Non-Loop master:** This L_Port shall receive and retransmit the Loop Initialization Sequences as identified in 10.4.

The Loop master selection is determined as follows:

(1) if a LISM sequence is received where the D_ID and Port_Name is equal to the D_ID and Port_Name of the L_Port, this L_Port becomes the Loop master.

(2) if ARB(F0) is received, another L_Port has become the Loop master.

(3) if a 10 second timer has elapsed before either condition (1) or (2) are met, the L_Port shall restart the initialization process by going to the INITIALIZATION state.

Once a Loop master has been selected, the following common events apply to all L_Ports while in the initialization procedure in 10.4:

— if CLS is recognized, initialization has completed. Before making the transition to the MONITORING state (see items 12 and 13), the Loop master shall discard the CLS; all other L_Ports shall retransmit the CLS;

— if LIP is recognized, the LPSM shall reenter the OPEN-INIT state (i.e., transmit at least twelve (12) LIPS of the same type as the last LIP received, etc.);

— if LPB is recognized:

- if x = AL_PA of the L_Port, the received LPB shall be discarded;

- if y = AL_PA of the L_Port or y = x'FF', the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13); or,

- if y <> AL_PA of the L_Port, the received LPByx shall be retransmitted.

— if LPE is recognized:

- if x = AL_PA of the L_Port, the received LPE shall be discarded or

- if x <> AL_PA of the L_Port, the received LPE shall be retransmitted.

If the L_Port requests to be bypassed (REQ(bypass L_Port)), the LPSM shall set the Bypass Circuit (if present); set LP_BYPASS to TRUE(1); and, make the transition to the MONITORING state. (See items 12 and 13).

If the L_Port requests another L_Port to be either bypassed or enabled (REQ(bypass L_Port y) or REQ(enable L_Port y) or REQ(enable all)), the LPSM shall transmit LPB or LPE until the Primitive Sequence is received.

If the L_Port no longer requires access to the Loop (REQ(nonparticipat.)), the LPSM shall make the transition to the MONITORING state. (See items 12 and 13).

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21.)

See table 13 for complete input, output, and state transition rules.

23 **State A (OLD-PORT) actions:** The LPSM shall set the current Fill Word to Idle; the L_Port shall process, but the LPSM shall not retransmit Transmission Words received on its inbound fibre. The L_Port shall transmit Primitive Signals, Primitive Sequences, or frames as specified in ANSI X3.230, FC-PH. Before Login[1], the "Alternate BB_Credit Management" bit shall be set to *0* and the BB_Credit shall be set to one (1).

The LPSM shall monitor for LIP. If LIP is recognized, the L_Port shall implicitly Logout with the other non-L_Port and shall make the transition to the OPEN-INIT state. (See items 2 and 22.)

If the LPSM detects a Loop failure on its inbound fibre or the L_Port requests initialization (REQ(initialize)), the LPSM shall make the transition to the INITIALIZING state. (See items 1 and 21 and clause 10.)

See table 14 for complete input, output, and state transition rules.

[1]Private NL_Ports may not support a Fabric Login.

9 L_Port state transition tables

This clause provides a summary of the transitions from one state to the next in the LPSM that are based directly on receipt of information from the inbound fibre or from L_Port controls. All inputs affecting the LPSM are repeated in each table to provide an exhaustive list of related outputs and transitions.

NOTES

1 Each Primitive Sequence entry in the following tables represents the point of recognition (i.e., the third consecutive Transmission Word of the same Ordered Set has been received). The entry labeled "ANY OTHER O.S." addresses the first and second Ordered Set of each Primitive Sequence. (See ANSI X3.230, FC-PH, 16.4.1.)

2 Requests to an L_Port which are not appropriate inputs may be ignored. Some implementations may choose to report an error status to the L_Port for these requests.

3 The entry labeled "ANY OTHER O.S." is used to process an Ordered Set which is a valid Transmission Word and which is not specifically accounted for in the State Table. This allows new Ordered Sets to be defined without disrupting previous implementations.

The ENTRY ACTIONS in the top block of tables 4-14 shall be completed before the LPSM shall recognize any condition specified in the column labeled 'INPUT.'

After initialization, an L_Port shall only set one control at a time (e.g., REQ(monitor)). Except for certain L_Port controls (e.g., REQ(bypass L_Port) and REQ(initialize)), received Primitive Signals and Sequences shall have higher priority than L_Port controls (i.e., the tables shall be processed from top to bottom).

The following abbreviations are used in tables 4 through 14:

app.	appropriate	**N/A**	Not Applicable to this state
CFW	Current Fill Word	**FP**	Framing Protocol
FC-2	FC-2 Protocol	**PSig**	FC-PH Primitive Signal(s)
Inst.	Instantaneous	**h-d**	half-duplex
PSeq	FC-PH Primitive Sequence(s)	**f-d**	full-duplex
N/C	No Change	**O.S.**	Ordered Set

Table 4 — MONITORING (State 0) transitions

ENTRY ACTIONS

ACCESS = N/C ARB_PEND = N/C ARB_WON = 0 DUPLEX = 0
REPLICATE = 0 CFW = N/C LP_BYPASS = N/C
If ARB_PEND = 1 and LP_BYPASS = 0, go to ARBITRATING state.
If ARB_PEND = 1 and LP_BYPASS = 1, set ARB_PEND = 0.

INPUT	OUTPUT	NEXT STATE
LOSS of SYNC. < R_T_TOV	Idle or CFW	MONITORING
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. CHAR	Any Valid T. Char.	MONITORING
RUNNING DISP at O.S.	CFW	MONITORING
ELASTICITY WORD REQD	CFW	MONITORING
VALID DATA WORD		
REPLICATE = 0	Same Word	MONITORING
REPLICATE = 1	Receive Word	
	Same Word	MONITORING
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx		
REPLICATE = 0	Same Word	MONITORING
REPLICATE = 1	Receive Word	
	Same Word	MONITORING
EOFxx		
REPLICATE = 0	Same Word	MONITORING
REPLICATE = 1	Receive Word	
	Same Word	MONITORING
PRIMITIVE SIGNALS		
Idle	CFW = Idle	
	ACCESS = 1	
	CFW	MONITORING
R_RDY	Same Word	MONITORING
ARB(F0)		
CFW = Idle	CFW	MONITORING
CFW <>Idle	CFW = ARB(F0)	
	CFW	MONITORING
ARBx		
non-participating	CFW = ARBx	
	CFW	MONITORING
participating		
x <>AL_PA	CFW = ARBx	
	CFW	MONITORING
x = AL_PA	CFW = Idle	
	CFW	MONITORING
OPNr (OPNfr¦OPNyr)		
non-participating	Same Word	MONITORING
participating		
f = hex 'FF'		
LP_BYPASS = 0	REPLICATE = 1	
	Same Word	MONITORING
LP_BYPASS = 1	Same Word	MONITORING
y = AL_PA		
LP_BYPASS = 0	REPLICATE = 1	
	Same Word	MONITORING
LP_BYPASS = 1	Same Word	MONITORING
All other OPNr	Same Word	MONITORING
OPNy		
non-participating	Same Word	MONITORING
participating		
y = AL_PA		
LP_BYPASS = 0	None/Inst.	OPENED
LP_BYPASS = 1	Same Word	MONITORING
y <>AL_PA	Same Word	MONITORING
CLS		
REPLICATE = 0	Same Word	MONITORING
REPLICATE = 1	REPLICATE = 0	
	Same Word	MONITORING
DHD	Same Word	MONITORING
MRKtx		
x = AL_PA	CFW	MONITORING
x <>AL_PA	Same Word	MONITORING

Continued on next page

Table 4 (concluded

PRIMITIVE SEQUENCES		
NOS	Same Word	MONITORING
OLS	Same Word	MONITORING
LR	Same Word	MONITORING
LRR	Same Word	MONITORING
LIP		
LP_BYPASS = 0	None/Inst.	OPEN-INIT
LP_BYPASS = 1	Same Word	non-participating MONITORING
LPB (LPByx¦LPBfx)		
x = AL_PA	CFW	MONITORING
y <>AL_PA	Same Word	MONITORING
y = AL_PA	LP_BYPASS = 1	
	Same Word	MONITORING
f = hex 'FF'	LP_BYPASS = 1	
	Same Word	MONITORING
LPE (LPEyx¦LPEfx)		
x = AL_PA	CFW	MONITORING
y <>AL_PA	Same Word	MONITORING
y = AL_PA	LP_BYPASS = 0	
	Same Word	MONITORING
f = hex 'FF'	LP_BYPASS = 0	
	Same Word	MONITORING
ANY OTHER O.S.	Same Word	MONITORING
L_PORT CONTROLS		
REQ(monitor)	None/Inst.	MONITORING
REQ(arbitrate as x)		
ACCESS = 0	None/Inst.	MONITORING
ACCESS = 1	None/Inst.	ARBITRATING
REQ(open yx) f-d	None/Inst.	MONITORING
REQ(open yy) h-d	None/Inst.	MONITORING
REQ(open fr)	None/Inst.	MONITORING
REQ(open yr)	None/Inst.	MONITORING
REQ(close)	None/Inst.	MONITORING
REQ(transfer)	None/Inst.	MONITORING
REQ(old-port)	None/Inst.	MONITORING
REQ(participating)	None/Inst.	INITIALIZING
REQ(nonparticipat.)	Transmit 12 LIPs	MONITORING
REQ(mark as tx)	MRKtx at the next app. Fill Word	MONITORING
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	MONITORING
REQ(bypass all)	None/Inst.	MONITORING
REQ(enable L_Port)	LP_BYPASS = 0	MONITORING
REQ(enable L_Port y)	None/Inst.	MONITORING
REQ(enable all)	None/Inst.	MONITORING
REQ(initialize)	None/Inst.	INITIALIZING

Table 5 — ARBITRATING (State 1) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = 1 ARB_WON = N/C DUPLEX = N/C REPLICATE = N/C CFW = N/C		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	Idle or CFW	ARBITRATING
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. CHAR	Any Valid T. Char.	ARBITRATING
RUNNING DISP at O.S.	CFW	ARBITRATING
ELASTICITY WORD REQD	CFW	ARBITRATING
VALID DATA WORD	Same Word	ARBITRATING
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	Same Word	ARBITRATING
EOFxx	Same Word	ARBITRATING
PRIMITIVE SIGNALS		
Idle	CFW = own ARBx	
	CFW	ARBITRATING
R_RDY	Same Word	ARBITRATING
ARBx		
AL_PA = hex 'F7'		
x = hex 'F0'	CFW = ARB(F7)	
	CFW	ARBITRATING
x < AL_PA	CFW = ARBx	
	CFW	ARBITRATING
x > AL_PA	CFW = own ARBx	
	CFW	ARBITRATING
x = AL_PA	None/Inst.	ARBITRATION WON
OPNr (OPNfr¦OPNyr)		
f = hex 'FF'	REPLICATE = 1	
	Same Word	ARBITRATING
y = AL_PA	REPLICATE = 1	
	Same Word	ARBITRATING
All other OPNr	Same Word	ARBITRATING
OPNy		
y <>AL_PA	Same Word	ARBITRATING
y = AL_PA	None/Inst.	OPENED
CLS		
REPLICATE = 0	Same Word	ARBITRATING
REPLICATE = 1	REPLICATE = 0	
	Same Word	ARBITRATING
DHD	Same Word	ARBITRATING
MRKtx		
x = AL_PA	CFW	ARBITRATING
x <>AL_PA	Same Word	ARBITRATING
PRIMITIVE SEQUENCES		
NOS	Same Word	ARBITRATING
OLS	Same Word	ARBITRATING
LR	Same Word	ARBITRATING
LRR	Same Word	ARBITRATING
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
y <>AL_PA	Same Word	ARBITRATING
y = AL_PA	LP_BYPASS = 1	
	None/Inst.	MONITORING
f = hex 'FF'	LP_BYPASS = 1	
	None/Inst.	MONITORING
LPE (LPEyx¦LPEfx)	Same Word	ARBITRATING
ANY OTHER O.S.	Same Word	ARBITRATING

Continued on next page

Table 5 (concluded)

L_PORT CONTROLS		
REQ(monitor)	None/Inst.	ARBITRATING
REQ(arbitrate as x)	None/Inst.	ARBITRATING
REQ(open yx) f-d	None/Inst.	ARBITRATING
REQ(open yy) h-d	None/Inst.	ARBITRATING
REQ(open fr)	None/Inst.	ARBITRATING
REQ(open yr)	None/Inst.	ARBITRATING
REQ(close)	None/Inst.	ARBITRATING
REQ(transfer)	None/Inst.	ARBITRATING
REQ(old-port)	None/Inst.	ARBITRATING
REQ(participating)	None/Inst.	ARBITRATING
REQ(nonparticipat.)	None/Inst.	ARBITRATING
REQ(mark as tx)	MRKtx at the next app. Fill Word	ARBITRATING
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	ARBITRATING
REQ(bypass all)	None/Inst.	ARBITRATING
REQ(enable L_Port)	None/Inst.	ARBITRATING
REQ(enable L_Port y)	None/Inst.	ARBITRATING
REQ(enable all)	None/Inst.	ARBITRATING
REQ(initialize)	None/Inst.	INITIALIZING

Table 6 — ARBITRATION WON (State 2) transitions

ENTRY ACTIONS ACCESS = 0 (fair) ARB_PEND = 0 ARB_WON = 1 ACCESS = 1 (unfair) DUPLEX = N/C CFW = ARB(F0) If AL_PA = hex 'F7', go to the INITIALIZING state. If REPLICATE = 1, transmit CLS and go to TRANSFER state.		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	N/A	N/A
LOOP FAILURE	N/A	N/A
INVALID TRANS. CHAR	N/A	N/A
RUNNING DISP at O.S.	N/A	N/A
ELASTICITY WORD REQD	N/A	N/A
VALID DATA WORD	N/A	N/A
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	N/A	N/A
EOFxx	N/A	N/A
PRIMITIVE SIGNALS		
Idle	N/A	N/A
R_RDY	N/A	N/A
ARBx	N/A	N/A
OPNr	N/A	N/A
OPNy	N/A	N/A
CLS	N/A	N/A
DHD	N/A	N/A
MRKtx	N/A	N/A
PRIMITIVE SEQUENCES		
NOS	N/A	N/A
OLS	N/A	N/A
LR	N/A	N/A
LRR	N/A	N/A
LIP	N/A	N/A
LPB (LPByx¦LPBfx)	N/A	N/A
LPE (LPEyx¦LPEfx)	N/A	N/A
ANY OTHER O.S.	N/A	N/A
L_PORT CONTROLS		
REQ(monitor)	N/A	N/A
REQ(arbitrate as x)	N/A	N/A
REQ(open yx) f-d	OPNyx	OPEN
REQ(open yy) h-d	OPNyy	OPEN
REQ(open fr)	OPNfr; REPLICATE=1	OPEN
REQ(open yr)	OPNyr; REPLICATE=1	OPEN
REQ(close)	OPNyy; y = AL_PA	OPEN
REQ(transfer)	N/A	N/A
REQ(old-port)	N/A	N/A
REQ(participating)	N/A	N/A
REQ(nonparticipat.)	N/A	N/A
REQ(mark as tx)	N/A	N/A
REQ(bypass L_Port)	N/A	N/A
REQ(bypass L_Port y)	N/A	N/A
REQ(bypass all)	N/A	N/A
REQ(enable L_Port)	N/A	N/A
REQ(enable L_Port y)	N/A	N/A
REQ(enable all)	N/A	N/A
REQ(initialize)	None/Inst.	INITIALIZATION

Table 7 — OPEN (State 3) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = N/C ARB_WON = N/C DUPLEX = N/C CFW = N/C Transmit at least six (6) CFWs and R_RDY (see 8.3.6)		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	FC-2 FP/PSig/PSeq	OPEN
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	FC-2 FP/PSig/PSeq	OPEN
RUNNING DISP at O.S.	FC-2 FP/PSig/PSeq	OPEN
ELASTICITY WORD REQD	N/A	OPEN
VALID DATA WORD	FC-2 FP/PSig/PSeq	OPEN
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	FC-2 FP/PSig/PSeq	OPEN
EOFxx	FC-2 FP/PSig/PSeq	OPEN
PRIMITIVE SIGNALS		
Idle	CFW = Idle ACCESS = 1	
	FC-2 FP/PSig/PSeq	OPEN
R_RDY	FC-2 FP/PSig/PSeq	OPEN
ARB(F0)	CFW = Idle	
	FC-2 FP/PSig/PSeq	OPEN
ARBx	FC-2 FP/PSig/PSeq	OPEN
OPNr	FC-2 FP/PSig/PSeq	OPEN
OPNy	FC-2 FP/PSig/PSeq	OPEN
CLS	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
DHD	FC-2 FP/PSig/PSeq	OPEN
MRKtx	FC-2 FP/PSig/PSeq	OPEN
PRIMITIVE SEQUENCES		
NOS	OLS	OPEN
OLS	LR	OPEN
LR	LRR	OPEN
LRR	Idle	OPEN
LIP	None/Inst.	OPEN-INIT
LPB (LPByx|LPBfx)		
x = AL_PA	FC-2 FP/PSig/PSeq	OPEN
y <>AL_PA	FC-2 FP/PSig/PSeq	OPEN
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx|LPEfx)	FC-2 FP/PSig/PSeq	OPEN
ANY OTHER O.S.	FC-2 FP/PSig/PSeq	OPEN

Continued on next page

Table 7 (concluded)

L_PORT CONTROLS		
REQ(monitor)	None/Inst.	OPEN
REQ(arbitrate as x)	None/Inst.	OPEN
REQ(open yx) f-d	None/Inst.	OPEN
REQ(open yy) h-d	None/Inst.	OPEN
REQ(open fr)		OPEN
REPLICATE = 0	None/Inst.	OPEN
REPLICATE = 1	OPNfr at the next app. Fill Word	OPEN
REQ(open yr)		
REPLICATE = 0	None/Inst.	OPEN
REPLICATE = 1	OPNyr at the next app. Fill Word	OPEN
REQ(close)		
Login DHD = 0	CLS at the next app. Fill Word	XMITTED CLOSE when CLS sent
Login DHD = 1	DHD at the next app. Fill Word	OPEN
REQ(transfer)		
ACCESS = 1	CLS at the next app. Fill Word	TRANSFER when CLS sent
ACCESS = 0	None/Inst.	OPEN
REQ(old-port)	None/Inst.	OPEN
REQ(participating)	None/Inst.	OPEN
REQ(nonparticipat.)	None/Inst.	OPEN
REQ(mark as tx)	MRKtx at the next app. Fill Word	OPEN
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	LPByx at the next Fill Word	OPEN
REQ(bypass all)	LPBfx at the next Fill Word	OPEN
REQ(enable L_Port)	None/Inst.	OPEN
REQ(enable L_Port y)	LPEyx at the next Fill Word	OPEN
REQ(enable all)	LPEfx at the next Fill Word	OPEN
REQ(initialize)	None/Inst.	INITIALIZING

Table 8 — OPENED (State 4) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = N/C DHD_RCV = 0 DUPLEX = 1 if OPNyx ARB_WON = 0 REPLICATE = 0 CFW = N/C DUPLEX = 0 if OPNyy Transmit at least six (6) CFWs and R_RDY (see 8.3.6)		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	FC-2 FP/PSig/PSeq	OPENED
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	FC-2 FP/PSig/PSeq	OPENED
RUNNING DISP at O.S.	FC-2 FP/PSig/PSeq	OPENED
ELASTICITY WORD REQD	N/A	OPENED
VALID DATA WORD	FC-2 FP/PSig/PSeq	OPENED
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	FC-2 FP/PSig/PSeq	OPENED
EOFxx	FC-2 FP/PSig/PSeq	OPENED
PRIMITIVE SIGNALS		
Idle		
ARB_PEND = 0	CFW = Idle	
	ACCESS = 1	
	FC-2 FP/PSig/PSeq	OPENED
ARB_PEND = 1	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	OPENED
R_RDY	FC-2 FP/PSig/PSeq	OPENED
ARBx		
ARB_PEND = 0		
x <>AL_PA	CFW = ARBx	
	FC-2 FP/PSig/PSeq	OPENED
x = AL_PA	CFW = ARB(F0)	
	FC-2 FP/PSig/PSeq	OPENED
ARB_PEND = 1		
x > AL_PA	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	OPENED
x = AL_PA	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	OPENED
x < AL_PA	CFW = ARBx	
	FC-2 FP/PSig/PSeq	OPENED
OPNr	FC-2 FP/PSig/PSeq	OPENED
OPNy	FC-2 FP/PSig/PSeq	OPENED
CLS	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
DHD	DHD_RCV = 1	OPENED
MRKtx	FC-2 FP/PSig/PSeq	OPENED
PRIMITIVE SEQUENCES		
NOS	OLS	OPENED
OLS	LR	OPENED
LR	LRR	OPENED
LRR	Idle	OPENED
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
y <>AL_PA	FC-2 FP/PSig/PSeq	OPENED
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)	FC-2 FP/PSig/PSeq	OPENED
ANY OTHER O.S.	FC-2 FP/PSig/PSeq	OPENED

Continued on next page

Table 8 (concluded)

L_PORT CONTROLS		
REQ(monitor)	None/Inst.	OPENED
REQ(arbitrate as x)	None/Inst.	OPENED
REQ(open yx) f-d	None/Inst.	OPENED
REQ(open yy) h-d	None/Inst.	OPENED
REQ(open fr)	None/Inst.	OPENED
REQ(open yr)	None/Inst.	OPENED
REQ(close)	CLS at the next app. Fill Word	XMITTED CLOSE when CLS sent
REQ(transfer)	None/Inst.	OPENED
REQ(old-port)	None/Inst.	OPENED
REQ(participating)	None/Inst.	OPENED
REQ(nonparticipat.)	None/Inst.	OPENED
REQ(mark as tx)	MRKtx at the next app. Fill Word	OPENED
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	OPENED
REQ(bypass all)	None/Inst.	OPENED
REQ(enable L_Port)	None/Inst.	OPENED
REQ(enable L_Port y)	None/Inst.	OPENED
REQ(enable all)	None/Inst.	OPENED
REQ(initialize)	None/Inst.	INITIALIZING

Table 9 — XMITTED CLOSE (State 5) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = N/C ARB_WON = N/C DUPLEX = N/C REPLICATE = N/C		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	Idle or CFW	XMITTED CLOSE
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	CFW	XMITTED CLOSE
RUNNING DISP at O.S.	CFW	XMITTED CLOSE
ELASTICITY WORD REQD	N/A	XMITTED CLOSE
VALID DATA WORD	CFW	XMITTED CLOSE
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	CFW	XMITTED CLOSE
EOFxx	CFW	XMITTED CLOSE
PRIMITIVE SIGNALS		
Idle		
ARB_PEND = 0	CFW = Idle	
	ACCESS = 1	
	CFW	XMITTED CLOSE
ARB_PEND = 1	CFW = own ARBx	
	CFW	XMITTED CLOSE
R_RDY	CFW	XMITTED CLOSE
ARB(F0)		
ARB_WON = 1	CFW = Idle	
	CFW	XMITTED CLOSE
ARB_WON = 0		
ARB_PEND = 0	CFW = ARB(F0)	
	CFW	XMITTED CLOSE
ARB_PEND = 1	CFW = own ARBx	
	CFW	XMITTED CLOSE
ARBx		
ARB_WON = 1	CFW	XMITTED CLOSE
ARB_WON = 0		
ARB_PEND = 0		
x <>AL_PA	CFW = ARBx	
	CFW	XMITTED CLOSE
x = AL_PA	CFW = ARB(F0)	
	CFW	XMITTED CLOSE
ARB_PEND = 1		
x > AL_PA	CFW = own ARBx	
	CFW	XMITTED CLOSE
x = AL_PA	CFW = own ARBx	
	CFW	XMITTED CLOSE
x < AL_PA	CFW = ARBx	
	CFW	XMITTED CLOSE
OPNr	CFW	XMITTED CLOSE
OPNy	CFW	XMITTED CLOSE
CLS	CFW	MONITORING
DHD	CFW	MONITORING
MRKtx		
x = AL_PA	CFW	XMITTED CLOSE
x <>AL_PA	Same Word	XMITTED CLOSE
PRIMITIVE SEQUENCES		
NOS	CFW	XMITTED CLOSE
OLS	CFW	XMITTED CLOSE
LR	CFW	XMITTED CLOSE
LRR	CFW	XMITTED CLOSE
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
y <>AL_PA	CFW	XMITTED CLOSE
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)	CFW	XMITTED CLOSE
ANY OTHER O.S.	CFW	XMITTED CLOSE

Continued on next page

Table 9 (concluded)

L_PORT CONTROLS		
REQ(monitor)	None/Inst.	MONITORING
REQ(arbitrate as x)	None/Inst.	XMITTED CLOSE
REQ(open yx) f-d	None/Inst.	XMITTED CLOSE
REQ(open yy) h-d	None/Inst.	XMITTED CLOSE
REQ(open fr)	None/Inst.	XMITTED CLOSE
REQ(open yr)	None/Inst.	XMITTED CLOSE
REQ(close)	None/Inst.	XMITTED CLOSE
REQ(transfer)	None/Inst.	XMITTED CLOSE
REQ(old-port)	None/Inst.	XMITTED CLOSE
REQ(participating)	None/Inst.	XMITTED CLOSE
REQ(nonparticipat.)	None/Inst.	XMITTED CLOSE
REQ(mark as tx)	MRKtx at the next app. Fill Word	XMITTED CLOSE
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	XMITTED CLOSE
REQ(bypass all)	None/Inst.	XMITTED CLOSE
REQ(enable L_Port)	None/Inst.	XMITTED CLOSE
REQ(enable L_Port y)	None/Inst.	XMITTED CLOSE
REQ(enable all)	None/Inst.	XMITTED CLOSE
REQ(initialize)	None/Inst.	INITIALIZING

Table 10 — RECEIVED CLOSE (State 6) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = N/C ARB_WON = N/C REPLICATE = 0 DUPLEX = N/C		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
RUNNING DISP at O.S.	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ELASTICITY WORD REQD	N/A	RECEIVED CLOSE
VALID DATA WORD	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
EOFxx	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
PRIMITIVE SIGNALS		
Idle		
ARB_PEND = 0	CFW = Idle	
	ACCESS = 1	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB_PEND = 1	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
R_RDY	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB(F0)		
ARB_WON = 1	CFW = Idle	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB_WON = 0		
ARB_PEND = 0	CFW = ARB(F0)	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB_PEND = 1	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARBx		
ARB_WON = 1	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB_WON = 0		
ARB_PEND = 0		
x <>AL_PA	CFW = ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
x = AL_PA	CFW = ARB(F0)	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ARB_PEND = 1		
x > AL_PA	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
x = AL_PA	CFW = own ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
x < AL_PA	CFW = ARBx	
	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
OPNr	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
OPNy	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
CLS	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
DHD	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
MRKtx	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
PRIMITIVE SEQUENCES		
NOS	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
OLS	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
LR	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
LRR	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
y <>AL_PA	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)	FC-2 FP/PSig/PSeq	RECEIVED CLOSE
ANY OTHER O.S.	FC-2 FP/PSig/PSeq	RECEIVED CLOSE

Continued on next page

Table 10 (concluded)

L_PORT CONTROLS		
REQ(monitor)	None/Inst.	RECEIVED CLOSE
REQ(arbitrate as x)	None/Inst.	RECEIVED CLOSE
REQ(open yx) f-d	None/Inst.	RECEIVED CLOSE
REQ(open yy) h-d	None/Inst.	RECEIVED CLOSE
REQ(open fr)	None/Inst.	RECEIVED CLOSE
REQ(open yr)	None/Inst.	RECEIVED CLOSE
REQ(close)	CLS at the next app. Fill Word	MONITORING when CLS sent
REQ(transfer)	None/Inst.	RECEIVED CLOSE
REQ(old-port)	None/Inst.	RECEIVED CLOSE
REQ(participating)	None/Inst.	RECEIVED CLOSE
REQ(nonparticipat.)	None/Inst.	RECEIVED CLOSE
REQ(mark as tx)	MRKtx at the next app. Fill Word	RECEIVED CLOSE
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	RECEIVED CLOSE
REQ(bypass all)	None/Inst.	RECEIVED CLOSE
REQ(enable L_Port)	None/Inst.	RECEIVED CLOSE
REQ(enable L_Port y)	None/Inst.	RECEIVED CLOSE
REQ(enable all)	None/Inst.	RECEIVED CLOSE
REQ(initialize)	None/Inst.	INITIALIZING

Table 11 — TRANSFER (State 7) transitions

ENTRY ACTIONS ACCESS = N/C ARB_PEND = N/C ARB_WON = N/C DUPLEX = N/C REPLICATE = 0		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	Idle or CFW	TRANSFER
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	CFW	TRANSFER
RUNNING DISP at O.S.	CFW	TRANSFER
ELASTICITY WORD REQD	N/A	TRANSFER
VALID DATA WORD	CFW	TRANSFER
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	CFW	TRANSFER
EOFxx	CFW	TRANSFER
PRIMITIVE SIGNALS		
Idle	CFW = Idle	
	ACCESS = 1	
	CFW	TRANSFER
R_RDY	CFW	TRANSFER
ARB(F0)	CFW = Idle	
	CFW	TRANSFER
ARBx	CFW	TRANSFER
OPNr	CFW	TRANSFER
OPNy	CFW	TRANSFER
CLS	None/Inst.	OPEN/MONITORING (L_PORT CONTROLS)
DHD	None/Inst.	TRANSFER
MRKtx		
x = AL_PA	CFW	TRANSFER
x <>AL_PA	Same Word	TRANSFER
PRIMITIVE SEQUENCES		
NOS	CFW	TRANSFER
OLS	CFW	TRANSFER
LR	CFW	TRANSFER
LRR	CFW	TRANSFER
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
y <>AL_PA	CFW	TRANSFER
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)	CFW	TRANSFER
ANY OTHER O.S.	CFW	TRANSFER

Continued on next page

Table 11 (concluded)

L_PORT CONTROLS		
REQ(monitor)	When CLS received	MONITORING
REQ(arbitrate as x)	None/Inst.	TRANSFER
REQ(open yx) f-d	When CLS received OPNyx	OPEN
REQ(open yy) h-d	When CLS received OPNyy	OPEN
REQ(open fr)	When CLS received OPNfr; REPLICATE=1	OPEN
REQ(open yr)	When CLS received OPNyr; REPLICATE=1	OPEN
REQ(close)	None/Inst.	TRANSFER
REQ(transfer)	None/Inst.	TRANSFER
REQ(old-port)	None/Inst.	TRANSFER
REQ(participating)	None/Inst.	TRANSFER
REQ(nonparticipat.)	None/Inst.	TRANSFER
REQ(mark as tx)	MRKtx at the next app. Fill Word	TRANSFER
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	None/Inst.	TRANSFER
REQ(bypass all)	None/Inst.	TRANSFER
REQ(enable L_Port)	None/Inst.	TRANSFER
REQ(enable L_Port y)	None/Inst.	TRANSFER
REQ(enable all)	None/Inst.	TRANSFER
REQ(initialize)	None/Inst.	INITIALIZING

Table 12 — INITIALIZING (State 8) transitions

ENTRY ACTIONS ACCESS = N/C DUPLEX = N/C ARB_WON = N/C REPLICATE = N/C Transmit twelve (12) LIPs CFW = N/C LP_BYPASS = 0		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	LIP	INITIALIZING
LOOP FAILURE	LIP	INITIALIZING
INVALID TRANS. WORD	LIP	INITIALIZING
RUNNING DISP at O.S.	LIP	INITIALIZING
ELASTICITY WORD REQD	N/A	INITIALIZING
VALID DATA WORD	LIP	INITIALIZING
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	LIP	INITIALIZING
EOFxx	LIP	INITIALIZING
PRIMITIVE SIGNALS		
Idle	LIP	INITIALIZING
R_RDY	LIP	INITIALIZING
ARBx	LIP	INITIALIZING
OPNr	LIP	INITIALIZING
OPNy	LIP	INITIALIZING
CLS	LIP	INITIALIZING
DHD	LIP	INITIALIZING
MRKtx	LIP	INITIALIZING
PRIMITIVE SEQUENCES		
NOS	LIP	INITIALIZING
OLS	LIP	INITIALIZING
LR	LIP	INITIALIZING
LRR	LIP	INITIALIZING
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)		
x = AL_PA	LIP	INITIALIZING
y <>AL_PA	Same Word	INITIALIZING
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)		
x = AL_PA	LIP	INITIALIZING
x <>AL_PA	Same Word	INITIALIZING
ANY OTHER O.S.	LIP	INITIALIZING
L_PORT CONTROLS		
REQ(monitor)	None/Inst.	INITIALIZING
REQ(arbitrate as x)	None/Inst.	INITIALIZING
REQ(open yx) f-d	None/Inst.	INITIALIZING
REQ(open yy) h-d	None/Inst.	INITIALIZING
REQ(open fr)	None/Inst.	INITIALIZING
REQ(open yr)	None/Inst.	INITIALIZING
REQ(close)	None/Inst.	INITIALIZING
REQ(transfer)	None/Inst.	INITIALIZING
REQ(old-port)	None/Inst.	OLD-PORT
REQ(participating)	None/Inst.	INITIALIZING
REQ(nonparticipat.)	None/Inst.	INITIALIZING
REQ(mark as tx)	None/Inst.	INITIALIZING
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	LPByx	INITIALIZING
REQ(bypass all)	LPBfx	INITIALIZING
REQ(enable L_Port)	None/Inst.	INITIALIZING
REQ(enable L_Port y)	LPEyx	INITIALIZING
REQ(enable all)	LPEfx	INITIALIZING
REQ(initialize)	None/Inst.	INITIALIZING

Table 13 — OPEN-INIT (State 9) transitions

ENTRY ACTIONS ACCESS = 1 DUPLEX = N/C ARB_WON = N/C REPLICATE = N/C Alternate BB_Credit = *1* BB_Credit = 0 CFW = Idle Transmit at least twelve (12) LIPs, then begin clause 10.		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	CFW	OPEN-INIT
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	CFW	OPEN-INIT
RUNNING DISP at O.S.	CFW	OPEN-INIT
ELASTICITY WORD REQD	N/A	OPEN-INIT
VALID DATA WORD	FC-2 FP/PSig/PSeq	OPEN-INIT
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	See clause 10	OPEN-INIT
EOFxx	See clause 10	OPEN-INIT
PRIMITIVE SIGNALS		
Idle	FC-2 FP/PSig/PSeq	OPEN-INIT
R_RDY	FC-2 FP/PSig/PSeq	OPEN-INIT
ARB(F0)		
(Loop master)	FC-2 FP/PSig/PSeq	OPEN-INIT
(other L_Ports)	ARB(F0)	OPEN-INIT
ARBx	CFW	OPEN-INIT
OPNr	FC-2 FP/PSig/PSeq	OPEN-INIT
OPNy	FC-2 FP/PSig/PSeq	OPEN-INIT
CLS (Loop master)	CFW	MONITORING
(other L_Ports)	CLS at the next app. Fill Word	MONITORING when CLS sent
DHD	FC-2 FP/PSig/PSeq	OPEN-INIT
MRKtx	FC-2 FP/PSig/PSeq	OPEN-INIT
PRIMITIVE SEQUENCES		
NOS	FC-2 FP/PSig/PSeq	OPEN-INIT
OLS	FC-2 FP/PSig/PSeq	OPEN-INIT
LR	FC-2 FP/PSig/PSeq	OPEN-INIT
LRR	FC-2 FP/PSig/PSeq	OPEN-INIT
LIP	None/Inst.	Reenter OPEN-INIT
LPB (LPByx¦LPBfx)		
x = AL_PA	FC-2 FP/PSig/PSeq	OPEN-INIT
y <>AL_PA	Same Word	OPEN-INIT
y = AL_PA	LP_BYPASS = 1	MONITORING
f = hex 'FF'	LP_BYPASS = 1	MONITORING
LPE (LPEyx¦LPEfx)		
x = AL_PA	FC-2 FP/PSig/PSeq	OPEN-INIT
x <>AL_PA	Same Word	OPEN-INIT
ANY OTHER O.S.	See clause 10	OPEN-INIT
L_PORT CONTROLS		
REQ(monitor)	None/Inst.	OPEN-INIT
REQ(arbitrate as x)	None/Inst.	OPEN-INIT
REQ(open yx) f-d	None/Inst.	OPEN-INIT
REQ(open yy) h-d	None/Inst.	OPEN-INIT
REQ(open fr)	None/Inst.	OPEN-INIT
REQ(open yr)	None/Inst.	OPEN-INIT
REQ(close)		
non-master	None/Inst.	OPEN-INIT
master	CLS	OPEN-INIT
REQ(transfer)	None/Inst.	OPEN-INIT
REQ(old-port)	None/Inst.	OPEN-INIT
REQ(participating)	None/Inst.	OPEN-INIT
REQ(nonparticipat.)	None/Inst.	MONITORING
REQ(mark as tx)	None/Inst.	OPEN-INIT
REQ(bypass L_Port)	LP_BYPASS = 1	MONITORING
REQ(bypass L_Port y)	LPByx	OPEN-INIT
REQ(bypass all)	LPBfx	OPEN-INIT
REQ(enable L_Port)	None/Inst.	OPEN-INIT
REQ(enable L_Port y)	LPEyx	OPEN-INIT
REQ(enable all)	LPEfx	OPEN-INIT
REQ(initialize)	None/Inst.	INITIALIZING

Table 14 — OLD-PORT (State A) transitions

ENTRY ACTIONS ACCESS = N/C DUPLEX = N/C ARB_WON = N/C REPLICATE = N/C Alternate BB_Credit = *0* BB_Credit = 1 CFW = Idle		
INPUT	**OUTPUT**	**NEXT STATE**
LOSS of SYNC. < R_T_TOV	FC-2 FP/PSig/PSeq	OLD-PORT
LOOP FAILURE	None/Inst.	INITIALIZING
INVALID TRANS. WORD	FC-2 FP/PSig/PSeq	OLD-PORT
RUNNING DISP at O.S.	FC-2 FP/PSig/PSeq	OLD-PORT
ELASTICITY WORD REQD	N/A	OLD-PORT
VALID DATA WORD	FC-2 FP/PSig/PSeq	OLD-PORT
VALID TRANS. WORD =O.S.		
FRAME DELIMITERS		
SOFxx	FC-2 FP/PSig/PSeq	OLD-PORT
EOFxx	FC-2 FP/PSig/PSeq	OLD-PORT
PRIMITIVE SIGNALS		
Idle	FC-2 FP/PSig/PSeq	OLD-PORT
R_RDY	FC-2 FP/PSig/PSeq	OLD-PORT
ARBx	FC-2 FP/PSig/PSeq	OLD-PORT
OPNr	FC-2 FP/PSig/PSeq	OLD-PORT
OPNy	FC-2 FP/PSig/PSeq	OLD-PORT
CLS	FC-2 FP/PSig/PSeq	OLD-PORT
DHD	FC-2 FP/PSig/PSeq	OLD-PORT
MRKtx	FC-2 FP/PSig/PSeq	OLD-PORT
PRIMITIVE SEQUENCES		
NOS	OLS	OLD-PORT
OLS	LR	OLD-PORT
LR	LRR	OLD-PORT
LRR	Idle	OLD-PORT
LIP	None/Inst.	OPEN-INIT
LPB (LPByx¦LPBfx)	FC-2 FP/PSig/PSeq	OLD-PORT
LPE (LPEyx¦LPEfx)	FC-2 FP/PSig/PSeq	OLD-PORT
ANY OTHER O.S.	FC-2 FP/PSig/PSeq	OLD-PORT
L_PORT CONTROLS		
REQ(monitor)	None/Inst.	OLD-PORT
REQ(arbitrate as x)	None/Inst.	OLD-PORT
REQ(open yx) f-d	None/Inst.	OLD-PORT
REQ(open yy) h-d	None/Inst.	OLD-PORT
REQ(open fr)	None/Inst.	OLD-PORT
REQ(open yr)	None/Inst.	OLD-PORT
REQ(close)	None/Inst.	OLD-PORT
REQ(transfer)	None/Inst.	OLD-PORT
REQ(old-port)	None/Inst.	OLD-PORT
REQ(participating)	None/Inst.	OLD-PORT
REQ(nonparticipat.)	None/Inst.	OLD-PORT
REQ(mark as tx)	None/Inst.	OLD-PORT
REQ(bypass L_Port)	None/Inst.	OLD-PORT
REQ(bypass L_Port y)	None/Inst.	OLD-PORT
REQ(bypass all)	None/Inst.	OLD-PORT
REQ(enable L_Port)	None/Inst.	OLD-PORT
REQ(enable L_Port y)	None/Inst.	OLD-PORT
REQ(enable all)	None/Inst.	OLD-PORT
REQ(initialize)	None/Inst.	INITIALIZING

10 Loop Initialization procedure

Loop Initialization is a logical procedure used by an L_Port to determine its environment and possibly to validate an AL_PA. During the procedure, the L_Port uses the LPSM and FC-2 protocol to discover its environment and react appropriately. At least a 132 byte receive buffer shall be available to receive each of the following Loop Initialization frames (see 10.4): LIFA, LIPA, LIHA, LISA, LIRP, and LILP; all other frames (i.e., LISM) may be discarded if the L_Port cannot accept the frame (e.g., buffers are full).

10.1 Initialization summary

A general summary of Loop Initialization follows (see 8.4.3, item 22 and table 13):

— During Loop Initialization (while in the OPEN-INIT state) only SOFiL shall be used to precede the Loop Initialization Sequences. R_RDYs shall not be used for flow-control and shall not be transmitted. If an R_RDY is received, it shall be discarded.

— If a non-L_Port is attached point-to-point to the L_Port, the L_Port finishes initialization in the OLD-PORT state and in non-participating mode. While in the OLD-PORT state, only FC-2 specified communication shall be used between the L_Port and the non-L_Port without further use of the Loop protocol.

— If two or more L_Ports are connected in a Loop without any non-L_Ports present, one FL_Port and up to 126 NL_Ports may finish initialization in the MONITORING state and in participating mode. FC-2 specified communication is used as permitted by the Loop LPSM.

— If one or more non-L_Ports are connected in a Loop with one or more L_Ports, the Loop is not operational.

  Arbitrary positioning of non-L_Ports on a Loop may cause one or more L_Ports to discover that at least one upstream device is an L_Port. However, the L_Ports are unable to successfully complete the remaining portions of the initialization procedure and remain in the initialization procedure.

— If more than one FL_Port or more than 126 NL_Ports are connected to a Loop, only one FL_Port and up to 126 NL_Ports shall enter participating mode. The remaining L_Ports operate in the MONITORING state and in non-participating mode.

  The initialization procedure permits a non-participating L_Port to attempt Loop Initialization after waiting an implementation-selected time or a participating L_Port may voluntarily yield its AL_PA. This allows the limited number of available AL_PAs to be shared.

  NOTE — If an L_Port in participating mode goes to non-participating mode, it invokes the Loop initialization protocol to allow another L_Port to use its AL_PA. (See 8.4.3, item 13.)

  IF a second FL_Port goes to the participating mode after the participating FL_Port goes to non-participating mode, all Public NL_Ports are implicitly logged out until Login with the new FL_Port has completed. All Private NL_Ports are implicitly logged out until Login with each NL_Port is reestablished.

— If an FL_Port exits the initialization procedure in participating mode, its AL_PA shall be hex '00' and it shall accept a D_ID of hex 'FFFFFE' as specified in ANSI X3.230, FC-PH. An NL_Port on the Loop may form a circuit with AL_PA hex '00' and shall receive normal Fabric topology responses from the FL_Port as specified in ANSI X3.230, FC-PH.

— If a Public NL_Port exits the initialization procedure in participating mode it attempts Login (if required in 10.4.3, step (5)) with the well-known address hex 'FFFFFE' through AL_PA hex '00' to obtain its native address identifier. (See ANSI X3.230, FC-PH, 21.4.7 and 23.3.1.)

— If an NL_Port exits the initialization procedure in participating mode and detects that an FL_Port is not in participating mode on the Loop, it may accept the responsibility of providing Fibre Channel services (e.g., recognize well-known addresses hex 'FFFFF0' to hex 'FFFFFE'). An NL_Port in this mode (known as an F/NL_Port) shall accept an alias AL_PA of hex '00' (in addition to its normal AL_PA) and recognize OPN(00,x), but shall not transmit ARB(00).

If an FL_Port initializes later than this F/NL_Port, the NL_Port shall no longer respond to alias AL_PA hex '00'.

10.2 Initialization introduction

An L_Port starts the Loop Initialization procedure by making the transition to the INITIALIZING state at the request of the node.

NOTE — Loop Initialization is disruptive (i.e., frames may be lost during initialization). To quiesce the Loop prior to issuing the first LIP, ARB(F7) may be used. If ARB(F7) is received, the L_Port may assume that the Loop is not being used by another L_Port and the L_Port may begin transmitting LIPs. ARB(F7) is used when the L_Port does not have an assigned AL_PA.

The main purpose of initializing is to acquire an AL_PA so that the L_Port may participate on the Loop. The AL_PA of a participating L_Port, and the corresponding priority of an NL_Port, may change each time the initialization procedure is invoked. The priority of the FL_Port is always the same.

An L_Port shall enter the OPEN-INIT state whenever any LIP is detected. This may interrupt two communicating L_Ports, but normal FC-PH error recovery (after returning to the MONITORING state) may be used to continue.

Figure 6 (see the end of 10.4) provides a flowchart-like view of the Loop Initialization procedure. The processes are represented as rectangles. The flows are represented as directed lines. The text in the diagram is brief and highly abbreviated. The major steps for the following subclauses are identified in the upper right-hand corner of selected process blocks.

10.3 Node-initiated L_Port initialization

This procedure is entered for one of the following reasons:

— to decide if a Loop is present at power-on;

— at the discretion of the Node (e.g., for Loop failures);

— whenever the AL_PA is modified during Fabric Login to the well-known address hex 'FFFFFE;' or,

— to acquire an AL_PA after a previous attempt was unsuccessful. (This would be the case if more than 126 NL_Ports or more than one FL_Port existed on the Loop.)

NOTE — Initialization may be disruptive. For this reason initializing should be used infrequently and the time delay between retrying is recommended to be in minutes.

The L_Port that is attempting to initialize shall make the transition to the INITIALIZING state (REQ(initialize)) (see 8.4.3, item 21) and shall enter non-participating mode. If the L_Port receives a LIP, it shall transfer to and remain in the OPEN-INIT state (LIP received) until initialization has completed, unless directed otherwise by the L_Port. (See 8.4.3.) If the LIP is not received within two (2) AL_TIME periods (and all attempts to recover from a Loop failure have failed), the L_Port shall complete initialization in the OLD-PORT state, except to invoke or react to the Loop Initialization procedure.

10.4 L_Port initialization

After the L_Port has performed the entry functions for the OPEN-INIT state (see 8.4.3, item 22), the L_Port shall continue initialization as defined in 10.4.3, steps (1) to (5). This initialization procedure uses the Loop Initialization Sequences as defined in figure 4.

10.4.1 Loop Initialization Sequences

Start_of_Frame delimiter - 4 bytes

SOFiL

Frame_Header - 24 bytes

22XXXXXX	00XXXXXX	01380000	00000000	FFFFFFFF	00000000

where 'XXXXXX' is hex '000000' for an FL_Port and hex '0000EF' for an NL_Port or F/NL_Port, or some other value specified by a future standard.

Payload - 12, 20, or 132 bytes

Loop Initialization identifier	8-byte Port_Name
	16-byte AL_PA bit map
	128-byte AL_PA position map (1-byte offset followed by up to 127 AL_PAs)

where the Loop Initialization identifier is one of the following codes and flags:

Codes (16 bits)

Value (hex)	**Name**	**Description**	**Payload size)**
'1101'	LISM	Select Master based on 8-byte Port_Name	(12-byte)
'1102'	LIFA	Fabric Assign AL_PA bit map	(20-byte)
'1103'	LIPA	Previously Acquired AL_PA bit map	(20-byte)
'1104'	LIHA	Hard Assigned AL_PA bit map	(20-byte)
'1105'	LISA	Soft Assigned AL_PA bit map	(20-byte)
'1106'	LIRP	Report AL_PA position map	(132-byte)
'1107'	LILP	Loop AL_PA position map	(132-byte)

Flags (16 bits; all 'x's are reserved--not checked, but transmitted as zero)

Identifier	**Flag**	**Mask (binary)**	**Meaning**
LISA	8	xxxx xxx1 xxxx xxxx	LIRP and LILP supported

Cyclic Redundancy Check - 4 bytes

CRC

End_of_Frame delimiter - 4 bytes

EOFt

Figure 4 — Loop Initialization Sequences

All FC-PH rules for valid frames apply to the Loop Initialization Sequences. Frames which are in error or that are not recognized as those shown in figure 4, shall be discarded. The contents of the Frame Header fields shall not be used to validate the Loop Initialization Sequences.

The one Loop Initialization Sequence that carries an 8-byte Port_Name is:

LISM — Select Master: used to assign a temporary Loop master (during Loop Initialization only).

The four Loop Initialization Sequences that carry a 16-byte AL_PA bit map are:

LIFA — Fabric Assigned: used to gather all Fabric Assigned AL_PAs.

LIPA — Previously Acquired: used to gather all Previously Acquired AL_PAs.

LIHA — Hard Assigned: used to gather all Hard Assigned AL_PAs (e.g., configuration switches (see annex K)).

LISA — Soft Assigned: used to assign any remaining bits as a Soft Assigned AL_PA.

The two Loop Initialization Sequences that carry a 128-byte AL_PA position map are:

LIRP — Report Position: used to collect the relative positions of all L_Ports on the Loop.

LILP — Loop Position: used to inform all L_Ports of their relative positions on the Loop from the perspective of the Loop Master.

10.4.2 Assigned AL_PA values

All AL_PAs that are used in the Loop protocol are specified in table 1. The AL_PAs are assigned to the 16-byte AL_PA bit maps of figure 5 as shown in table 15.

Table 15 — AL_PA mapped to bit maps

AL_PA (hex)	Bit Map Word	Bit	AL_PA (hex)	Bit Map Word	Bit	AL_PA (hex)	Bit Map Word	Bit	AL_PA (hex)	Bit Map Word	Bit
--	0	31	3C	1	31	73	2	31	B3	3	31
00	0	30	43	1	30	74	2	30	B4	3	30
01	0	29	45	1	29	75	2	29	B5	3	29
02	0	28	46	1	28	76	2	28	B6	3	28
04	0	27	47	1	27	79	2	27	B9	3	27
08	0	26	49	1	26	7A	2	26	BA	3	26
0F	0	25	4A	1	25	7C	2	25	BC	3	25
10	0	24	4B	1	24	80	2	24	C3	3	24
17	0	23	4C	1	23	81	2	23	C5	3	23
18	0	22	4D	1	22	82	2	22	C6	3	22
1B	0	21	4E	1	21	84	2	21	C7	3	21
1D	0	20	51	1	20	88	2	20	C9	3	20
1E	0	19	52	1	19	8F	2	19	CA	3	19
1F	0	18	53	1	18	90	2	18	CB	3	18
23	0	17	54	1	17	97	2	17	CC	3	17
25	0	16	55	1	16	98	2	16	CD	3	16
26	0	15	56	1	15	9B	2	15	CE	3	15
27	0	14	59	1	14	9D	2	14	D1	3	14
29	0	13	5A	1	13	9E	2	13	D2	3	13
2A	0	12	5C	1	12	9F	2	12	D3	3	12
2B	0	11	63	1	11	A3	2	11	D4	3	11
2C	0	10	65	1	10	A5	2	10	D5	3	10
2D	0	9	66	1	9	A6	2	9	D6	3	9
2E	0	8	67	1	8	A7	2	8	D9	3	8
31	0	7	69	1	7	A9	2	7	DA	3	7
32	0	6	6A	1	6	AA	2	6	DC	3	6
33	0	5	6B	1	5	AB	2	5	E0	3	5
34	0	4	6C	1	4	AC	2	4	E1	3	4
35	0	3	6D	1	3	AD	2	3	E2	3	3
36	0	2	6E	1	2	AE	2	2	E4	3	2
39	0	1	71	1	1	B1	2	1	E8	3	1
3A	0	0	72	1	0	B2	2	0	EF	3	0

Note — '--' is reserved for the L_bit (Login required);
AL_PA = '00' is reserved for the FL_Port

10.4.3 Initialization steps

The following initialization steps are performed unless one of the common events identified in 8.4.3, item 22, occurs. Until the LISA frame has been processed, AL_PAs may be unstable and any Primitive Sequence (e.g., LPByx) may not be acted upon by the desired L_Port.

1) Select initial AL_PA

Each FL_Port shall choose an initial value for its AL_PA of hex '00'.

Each NL_Port shall choose an initial value for its AL_PA of hex 'EF'.

Because of these initial AL_PA values, until the L_Port establishes a new AL_PA in step (4), only FL_Ports and NL_Ports can be uniquely distinguished with an LPByx. For example, if an NL_Port transmits LPB(EF,x), it has the effect of bypassing all other NL_Port.

If an NL_Port implements the Loop master function and that function is enabled, the NL_Port shall continue at step (2); otherwise, the NL_Port shall continue at step (3).

2) Select a Loop master

The L_Port shall transmit Loop Initialization Sequences (identifier='LISM') formatted as shown in figure 4. Successive Loop Initialization Sequences shall be separated by six or more Idles.

NOTE — Frames are sent continuously because they may be discarded by any L_Port that does not have a receive buffer available (flow control is not used during initialization).

The L_Port shall transmit the Loop Initialization Sequence (identifier='LISM') until either:

a) a valid Loop Initialization Sequence (identifier='LISM') is received that is identical to the Loop Initialization Sequence which the L_Port initially transmitted. The L_Port shall become the Loop master and shall continue at step (4).

b) a valid Loop Initialization Sequence (identifier='LISM') is received; the L_Port shall check the D_ID and Port_Name as follows (all fields other than the D_ID and Port_Name shall be ignored when determining whether the received Loop Initialization Sequence is algebraically lower):

— if the received D_ID is lower than the D_ID value initially transmitted, then the receive Loop Initialization Sequence is algebraically lower. The L_Port shall continue at step (3).

— if the received D_ID is equal to the D_ID value initially transmitted and the 8-byte received Port_Name is algebraically lower than the Port_Name initially transmitted, then the received Loop Initialization Sequence is algebraically lower. The L_Port shall continue at step (3).

— if the received Loop Initialization Sequence is not algebraically lower, the L_Port shall repeat steps (2)(a) to (2)(b).

3) Wait for a Loop master

The L_Port shall receive and retransmit valid frames until the L_Port receives ARB(F0). An L_Port shall wait up to 10 seconds for ARB(F0). If the timer expires before ARB(F0) is received (no Loop master was selected), the L_Port shall go to the INITIALIZING state.

4) Loop master — transmit remaining Loop Initialization Sequences

a) The Loop master shall continuously transmit ARB(F0)s until ARB(F0) is received.

b) The L_Port shall transmit the Loop Initialization Sequences (identifier='LIFA', 'LIPA', 'LIHA', and 'LISA'). These Loop Initialization Sequences contain a 16-byte AL_PA bit map in the payload. Each bit represents one AL_PA (see figures 4 and 5 and table 15).

	Bits							
Word	3322 1098	2222 7654	2222 3210	1111 9876	1111 5432	11 1098	7654	3210
0	L000	0000	0000	0000	0000	0000	0000	0000
1	0000	0000	0000	0000	0000	0000	0000	0000
2	0000	0000	0000	0000	0000	0000	0000	0000
3	0000	0000	0000	0000	0000	0000	0000	0000

where 'L' is the Login Required bit (L_bit).

Figure 5 — Loop Initialization Sequence AL_PA bit map

Except for the L_bit, each bit in figure 5 represents a valid AL_PA (according to tables 1 and 15). The L_bit shall only be set by the FL_Port or F/NL_Port to indicate that the configuration has changed. Setting the L_bit shall implicitly logout all NL_Ports (i.e., Public NL_Ports shall perform a Fabric Login; Private NL_Ports shall accept only a Login request).

NOTE — Private NL_Ports are also implicitly logged out since the Public NL_Ports with which they may have been communicating, may have a new AL_PA.

The Loop master shall transmit the four Loop Initialization Sequences that contain the 16-byte AL_PA bit maps as follows:

LIFA The L_Port shall prime the AL_PA bit map with binary zero (*0*) and shall set to one (*1*) the bit that corresponds to its Fabric Assigned AL_PA. If the L_Port is an FL_Port, it shall set the bit associated with AL_PA hex '00'. The L_bit shall also be set if this is the first initialization attempt of an FL_Port or of an NL_Port that has assumed the role of an F/NL_Port.

LIPA The L_Port shall prime the AL_PA bit map with the AL_PA bit map of the previous Loop Initialization Sequence (identifier='LIFA'). The L_Port shall check if the bit that corresponds to its Previously Acquired AL_PA is set. If it is not set to 1, the L_Port shall set the bit (unless a bit was set in LIFA); if the bit is already set to 1, the L_Port shall assume a Soft Assigned AL_PA.

LIHA The L_Port shall prime the AL_PA bit map with the AL_PA bit map of the previous Loop Initialization Sequence (identifier='LIPA'). The L_Port shall check if the bit that corresponds to its Hard Assigned AL_PA is set. If it is not set to 1, the L_Port shall set the bit (unless a bit was set in LIFA or LIPA); if the bit is already set to 1, the L_Port shall assume a Soft Assigned AL_PA.

LISA The L_Port shall prime the AL_PA bit map with the AL_PA bit map of the previous Loop Initialization Sequence (identifier='LIHA'). The L_Port shall set the first available bit to 1 (unless a bit was set in LIFA, LIPA, or LIHA) which corresponds to its Soft Assigned AL_PA. If a bit was available, the L_Port shall adjust its AL_PA according to which bit it set. If no bits are available, the L_Port shall remain in the non-participating mode; the L_Port may attempt to re-initialize at 10.3 at the request of the Node. If the L_Port does not support the AL_PA position mapping Loop Initialization Sequences, it shall set byte 2 of the Loop Initialization identifier to hex '00'.

c) When the Loop master receives the LISA Sequence, it shall check the Loop Initialization Flags. If Flag 8 is set to one (1), the Loop master shall transmit two additional Loop Initialization Sequences as follows:

LIRP The L_Port shall set the AL_PA position map to all hex 'FF', shall enter an offset of hex '01', followed by its AL_PA. For example, if AL_PA = hex '05', the AL_PA position map contains hex '0105FFFFFF...FF'.

LILP The L_Port shall transmit the AL_PA position map of the previous Loop Initialization Sequence (identifier='LIRP').

d) When the last Loop Initialization Sequence (identifier='LISA' or 'LILP') is returned, the Loop master shall transmit CLS to place all L_Ports into the MONITORING state. When CLS is received by the Loop master, the L_Port shall make the transition to the MONITORING state and relinquish its Loop master role. At this time, all possible AL_PA values have been assigned for the number of L_Ports and every L_Port that has a valid AL_PA shall be in participating mode.

If any frame is received that is not formatted according to figure 4, the frame shall be discarded and the Loop master shall restart initialization at step (3)(b).

The Loop master shall use the E_D_TOV timer to wait for each of the above Loop Initialization Sequences and the CLS. If the timer expires before each transmitted Loop Initialization Sequence or CLS is received, the L_Port shall go to the INITIALIZING state.

The L_Port shall continue at step (6).

5) Non_Loop master L_Port — select unique AL_PA

A non_Loop master L_Port shall retransmit any received ARB(F0)s and shall prepare to receive (e.g., empty its receive buffers) and retransmit the following Loop Initialization Sequences (identifier='LIFA', 'LIPA', 'LIHA', 'LISA', 'LIRP', and 'LILP'), followed by CLS. The L_Port shall clear any Loop Initialization Flags which it does not recognize before retransmitting the Loop Initialization Sequences.

The Loop Initialization Sequences are updated as follows (see figures 4 and 5 and table 15):

LIFA The L_Port shall check if the bit that corresponds to its Fabric Assigned AL_PA is set. If it is not set to 1, the L_Port shall set the bit; if the bit is already set to 1, the L_Port shall assume a Soft Assigned AL_PA. The L_Port shall retransmit the Loop Initialization Sequence.

LIPA The L_Port shall check if the bit that corresponds to its Previously Acquired AL_PA is set. If it is not set to 1, the L_Port shall set the bit (unless a bit was set in LIFA); if the bit is already set to 1, the L_Port shall assume a Soft Assigned AL_PA. The L_Port shall retransmit the Loop Initialization Sequence.

LIHA The L_Port shall check if the bit that corresponds to its Hard Assigned AL_PA is set. If it is not set to 1, the L_Port shall set the bit (unless a bit was set in LIFA or LIPA); if the bit is already set to 1, the L_Port shall assume a Soft Assigned AL_PA. The L_Port shall retransmit the Loop Initialization Sequence.

LISA The L_Port shall set the first available bit to 1 (unless a bit was set in LIFA, LIPA, or LIHA) that corresponds to its Soft Assigned AL_PA. If a bit was available, the L_Port shall adjust its AL_PA according to which bit was set. If no bits are available, the L_Port shall remain in the non-participating mode; the L_Port may attempt to re-initialize at 10.3 at the request of the Node. The L_Port shall retransmit the Loop Initialization Sequence.

LIRP If LIRP is received, the L_Port shall read the left-most byte (offset), increment it by one, store the offset, and store its AL_PA into the offset position. The L_Port shall retransmit the Loop Initialization Sequence.

LILP If LILP is received, the L_Port may use the AL_PA position map to save the relative positions of all L_Ports on the Loop. This information may be useful for error recovery. The L_Port shall retransmit the Loop Initialization Sequence.

The L_Port shall discard all invalid or unrecognized Loop Initialization Sequences which are not formatted according to figure 4 and as specified in 10.4.3, step (4).

When CLS is received, the L_Port shall retransmit CLS and shall continue at step (6).

6) Select final AL_PA and exit initialization

a) If an FL_Port is in participating mode, it has completed initialization with an AL_PA of hex '00' and shall exit the Loop initialization.

b) If a Private NL_Port is in participating mode, the NL_Port has completed initialization with an AL_PA in the range of hex '01' through hex 'EF' and shall exit Loop initialization. If during initialization, the NL_Port detected that the L_bit (Login required) was set to 1, it shall implicitly logout with all other NL_Ports.

c) If a Public NL_Port is in participating mode, the NL_Port shall have discovered an AL_PA in the range of hex '01' through hex 'EF'. If one of the following occurred (see ANSI X3.230, FC-PH, 23.3.1), the NL_Port shall implicitly logout with all Ports and attempt a Fabric Login to the well-known address hex 'FFFFFE' through AL_PA hex '00':

— the NL_Port detected that the L_bit (Login required) was set to 1 in a Loop Initialization Sequence (identifier='LIFA', 'LIPA', 'LIHA', or 'LISA');

— the NL_Port was unable to set to 1 its Fabric Assigned AL_PA bit or its Previously Acquired AL_PA bit in the Loop Initialization Sequence (identifier='LIFA' or 'LIPA') (i.e., another NL_Port is using the AL_PA); or,

— the NL_Port has not previously executed a Fabric Login.

Normal responses to a Fabric Login request are:

— the transmitted OPN(00,AL_PS) and Login Extended Link Service Sequence are returned to the NL_Port. No L_Port on the Loop has accepted this request. The NL_Port shall set its native address identifier to hex '0000XX' (where 'XX' is its AL_PA).

If the NL_Port is capable of providing Fabric services in the absence of an FL_Port (i.e., it recognizes the well-known alias address hex 'FFFFFE' as well as its own native address identifier), this NL_Port (known as an F/NL_Port) shall recognize OPN(00,x) in addition to its own AL_PA. If this is the first time that the NL_Port is assuming the responsibility of an F/NL_Port, to ensure that all previous Login requests are reset, the F/NL_Port shall go to the INITIALIZING state (REQ(initialize)) and set the L_bit (Login required) to 1 in the Loop Initialization Sequence (identifier='LIFA');

NOTE — To prevent another L_Port from winning arbitration, this F/NL_Port should not relinquish control of the Loop (i.e., not transmit CLS or go to the INITIALIZING state) until it is prepared to receive OPN(00,AL_PS).

If the NL_Port is not capable of becoming an F/NL_Port, the NL_Port shall exit Loop initialization.

— the NL_Port receives an Accept (ACC) Link Service Sequence. The NL_Port shall use the D_ID in the ACC Sequence as its native address identifier and bits 7-0 of the D_ID as its Fabric Assigned AL_PA. The NL_Port shall compare the Fabric Assigned AL_PA in the ACC sequence with the AL_PA acquired prior to step (5):

- if they are equal, the NL_Port shall exit Loop Initialization or

- if they are unequal, the NL_Port shall go to the INITIALIZING state (REQ(initialize)) to re-initialize and acquire the Fabric Assigned AL_PA value.

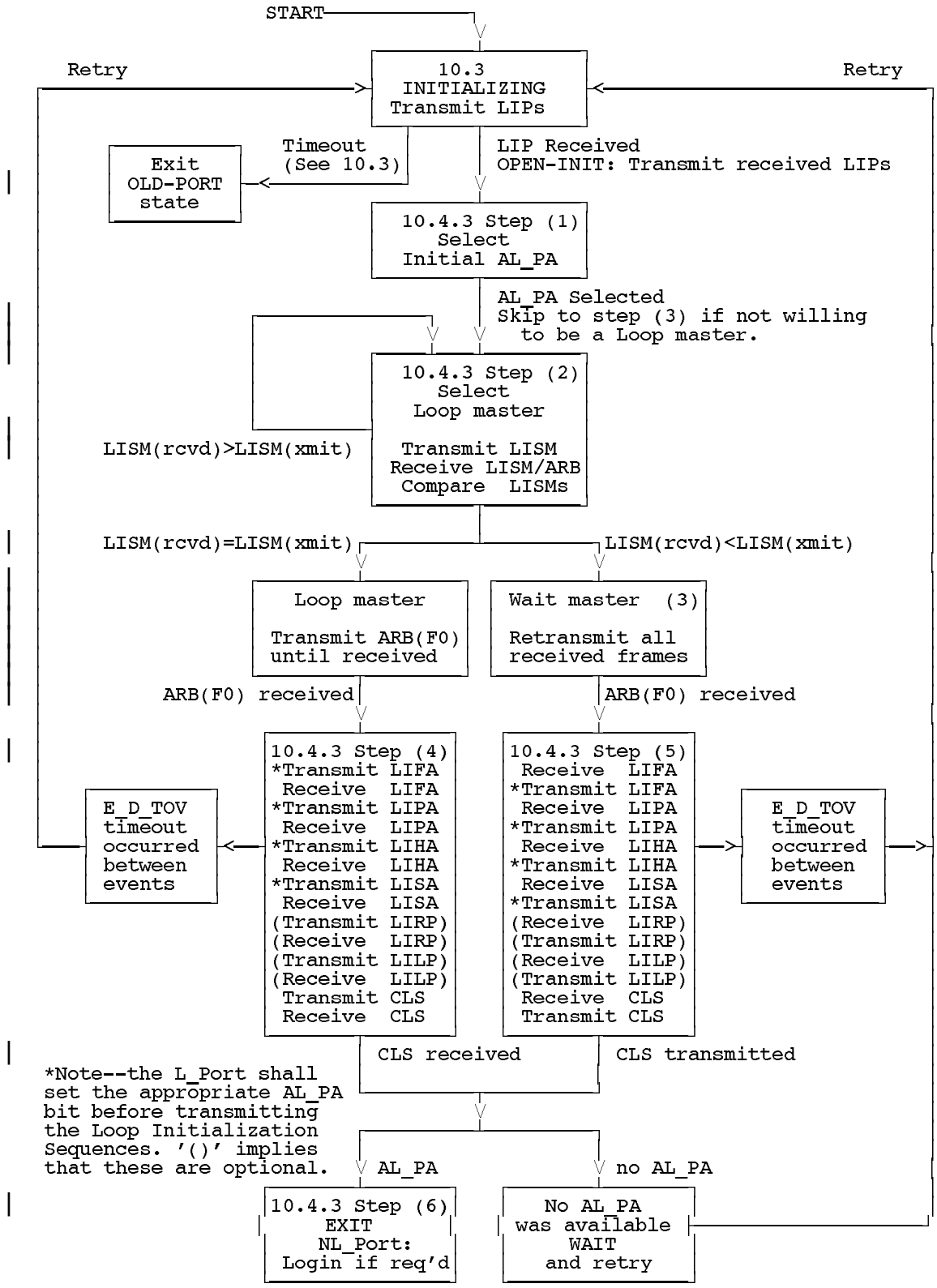


Figure 6 — L_Port initialization procedure

Annex A
(informative)

Loop Port State Machine examples

The two examples in this annex use nine of the eleven states in the LPSM (see 8.4 for states and items) and eleven of the twenty-three state transitions. Of the twelve unused state transitions, four are for rare events or error handling. Therefore, much of the Loop protocol is covered in these two simple examples.

A.1 Node initialization example

The general, error free procedure for taking the LPSM of a Public NL_Port through Loop Initialization to the point of Fabric Login follows (see clause 8 for reference items and LPSM transitions):

— The NL_Port powers on and attempts to join the Loop;

— The NL_Port uses hex ‘F7' (since it does not have an AL_PA) to instruct the LPSM to arbitrate (REQ(arbitrate as x)) and to initialize (REQ(initialize)).

The LPSM makes transition (01);

— The LPSM, now in the ARBITRATION state, begins to replace any Idle or ARB(F0) with ARB(F7) and monitors its inbound fibre for ARB(F7). (See 8.4.3 item 14 for details);

The LPSM makes transition (12);

— The LPSM detects ARB(F7) and recognizes (REQ(initialize)). (See 8.4.3 item 15 for details);.

The LPSM makes transition (28);

— The LPSM, now in the INITIALIZING state, begins to transmit LIP(F7,F7) and monitors its inbound fibre for LIP. (See 8.4.3, item 21 for details);

— The LPSM detects LIP.

The LPSM makes transition (89);

— The LPSM, now in the OPEN-INIT state, sets ACCESS to TRUE(1), transmits at least twelve (12) received LIPs, continuously transmits the Loop Initialization Sequence (identifier='LISM'), and monitors its inbound fibre for a Loop Initialization Sequence (identifier='LISM' or for ARB(F0)). (See 8.4.3, item 22 for details.)

- ARB(F0) is received (this indicates that a Loop master has been selected).

- The L_Port sets its AL_PA bit and AL_PA value in the appropriate Loop Initialization Sequence AL_PA bit map (identifier='LIFA', 'LIPA', 'LIHA', 'LISA') and AL_PA position map (identifier='LIRP'), respectively, and retransmits them.

- The L_Port monitors it inbound fibre for CLS sent by the Loop master.

— The LPSM detects CLS.

The LPSM makes transition (90);

— The NL_Port, now in the MONITORING state, is ready to execute a Fabric Login if it is a Public NL_Port. (See 10.4, step (5).)

The complete list of state transitions and states in the order used is: (01), 1: ARBITRATING; (12) 2: ARBITRATION WON; (28), 8: INITIALIZING; (89), 9: OPEN-INIT; (90), 0: MONITORING.

A.2 N_Port Login example

After the NL_Port initialization procedure has completed (see 10.4), and the NL_Port has a native address identifier (and an AL_PA) and is in participating mode, a general, error-free procedure for performing NL_Port Login with another NL_Port is described below. In this example, one NL_Port AL_PA is hex '26'; the other NL_Port AL_PA is hex '32'. The example assumes: there is no participating FL_Port; the arbitrating NL_Port is using the fairness algorithm; BB_Credit is the default value zero (0) for both NL_Ports; and, both NL_Ports start from the MONITORING state.

— NL_Port 26 arbitrates to access the Loop (REQ(arbitrate as 26)). Assume that the variable ACCESS is set to TRUE(1). (See 8.4.3, item 14 for details.)

The LPSM makes transition (01);

— NL_Port 26, now in the ARBITRATING state, can arbitrate because its access window has been reset (ACCESS is TRUE(1). The LPSM begins replacing all Idles and lower priority ARBx with its own ARB(26). (See 8.4.3, item 14 for details.)

The LPSM monitors for ARB(26) on its inbound fibre.

Assuming no higher priority NL_Port is arbitrating, ARB(26) is received.

The LPSM makes transition (12);

— NL_Port 26, now in the ARBITRATION WON state, must decide whether to open the Loop or not. ACCESS is set to FALSE(0). In this example, the Loop is to be opened (REQ(open 32,26)). (See 8.4.3, item 15 for details.)

The NL_Port 26 transmits OPN(32,26) to cause the other NL_Port to go to the OPENED state in full-duplex mode.

The LPSM makes transition (23);

— NL_Port 26, now in the OPEN state in full-duplex mode, follows OPN(32,26) with one or more R_RDY (one for each available receive buffer) and the current Fill Word until a frame is transmitted. ARB_WON is set to TRUE(1). (See 8.4.3, item 16 for details.)

Concurrently, NL_Port 32, in the MONITORING state, receives OPN(32,26) and goes to the OPENED state.

The LPSM for NL_Port 32 makes transition (04);

— NL_Port 32, now in the OPENED state, transmits the current Fill Word to replace OPN(32,26) on the Loop, followed by one or more R_RDYs (one for each available receive buffer) and the current Fill Word until a frame is transmitted. ARB_WON is set to FALSE(0). DUPLEX is set to TRUE(1). (See 8.4.3, item 17 for details);

— NL_Port 26 is in the OPEN state and NL_Port 32 is in the OPENED state.

A circuit has been established between the two NL_Ports. Since BB_Credit was zero (0), at least one R_RDY must be received before a frame may be transmitted by each NL_Port (i.e., normal ANSI X3.230, FC-PH Login protocol can now be used);

— NL_Port 26 and NL_Port 32 have previously (during L_Port initialization) determined that there is no Fabric. NL_Port 26 transmits an N_Port Login Sequence with D_ID of hex '000032' and S_ID of hex '000026'. Both NL_Ports recognize these as legitimate native address identifiers for a Loop without an FL_Port. The current Fill Word again follows transmission of the Sequence.

The N_Port Login Sequence arrives at NL_Port 32 and is processed; an R_RDY is transmitted when the receive buffer becomes available;

— NL_Port 32 transmits an Accept response to NL_Port 26 honoring its requested native address identifier and confirming its own native address identifier.

NL_Port 26 receives the Accept Sequence and begins to close the Loop (REQ(close)) by transmitting a CLS, followed by the current Fill Word (note that an R_RDY was not required). (See 8.4.3, item 18 for details.)

The LPSM for NL_Port 26 makes transition (35) to the XMITTED CLOSE state;

— The CLS is received by NL_Port 32.

The LPSM for NL_Port 32 makes transition (46);

— The LPSM for NL_Port 32, now in the RECEIVED CLOSE state, transmits CLS (REQ(close)). (See 8.4.3, item 19 for details.)

The LPSM for NL_Port 32 makes transition (60);

— The LPSM for NL_Port 32, now in the MONITORING state, has completed its work for the circuit. NL_Port 32 may begin arbitrating to carry out its own work;

— The LPSM for NL_Port 26, now in the XMITTED CLOSE state, monitors its inbound fibre for CLS. (See 8.4.3, item 18 for details.)

The CLS is received on its inbound fibre.

The LPSM for NL_Port 26 makes transition (50);

— The LPSM for NL_Port 26, now in the MONITORING state, has completed its work for the circuit. If NL_Port 26 is a fair L_Port, it must now wait until an Idle is seen (i.e., ACCESS is TRUE(1)) before it can attempt to arbitrate again.

NOTE — If no other L_Port had been arbitrating, NL_Port 26 could have used the TRANSFER state if it required further use of the Loop.

The complete list of state transitions and states in the order used are:

NL_Port 26
0: MONITORING, (01)
1: ARBITRATING, (12)
2: ARBITRATION WON, (23)
3: OPEN, (35)
5: XMITTED CLOSE, (50)
0: MONITORING

NL_Port 32
0: MONITORING, (04)
4: OPENED, (46)
6: RECEIVED CLOSE, (60)
0: MONITORING

Annex B
(informative)

Dynamic Half-Duplex

Although Fibre Channel is by nature a full-duplex link (i.e., Data frames may travel in both directions in the fibre pairs simultaneously), some L_Port implementation can only support one-directional data transfers. There are two types of L_Ports possible:

1) Full-duplex L_Ports are those that may simultaneously transmit and receive Data frames (this type of Data frame transfer is referred to *bi-directional transfer*).

2) Half-duplex L_Ports are those which can transmit or receive Data frames, but not at the same time (this type of Data frame transfer is referred to as *simplex transfer*).

This annex describes a method to minimize the number or arbitration cycles by using the established circuit more efficiently. The description is independent of which Class of Service is being used.

B.1 Close initiative description

Although, not required by FC-AL, the L_Port in the OPEN state normally transmits the first CLS to close the Loop. When a full-duplex circuit exists (i.e., OPNyx was transmitted and the L_Port in the OPENED state receives CLS, it may continue to transmit frames until has no more credit (i.e., Available_BB_Credit=0 or EE_Credit=0). Once the OPENED L_Port is no longer able to transmit any frames, it must forward CLS. This assumes that both L_Ports may have transferred Data frames in opposite directions when a full-duplex circuit exists.

NOTE — An L_Port which has transmitted CLS is not allowed to transmit any frames or R_RDYs.

There are at least two cases where it may be useful to transfer the close initiative rather than transmitting CLS to allow the L_Port which holds the close initiative to transmit the first CLS.

1) Some implementation are not able to handle simultaneous transmit and receive data transfers at the node. Often, these nodes have Data frames pending for the OPEN L_Port, but because of the implementation, cannot take advantage of the bi-directional circuit which exists.

2) Even if full-duplex data transfers are possible, if the OPEN L_Port transmits CLS, the OPENED L_Port can only transmit Data frames based on existing credit.

Both of these cases would require a re-arbitration to transmit the Data frames which an L_Port was unable to transmit..

To avoid this extra re-arbitration cycle, the DHD Primitive Signal is provided. DHD is transmitted by the OPEN L_Port instead of transmitting CLS. Transmitting DHD allows the OPEN L_Port to continue to transmit R_RDYs and Link Control frames (but no Data frames). The OPENED L_Port remembers that it has received DHD by setting the DHD_RCV flag. If DHD_RCV is TRUE(1), the OPENED L_Port holds the close initiative and is expected to transmit the first CLS when it has no more frames to transmit to the OPEN L_Port.

B.2 Dynamic Half-Duplex examples

Table B.1 describes how two L_Ports (**A** in the OPEN state and **B** in the OPENED state) may make better use of a full-duplex circuit by using DHD. Table B.1 shows both R_RDY and Link_Control frame flow control. If the Class of Service does not use one or the other, these would be absent from the table.

NOTE — Once the close initiative is transferred from one L_Port to the other via DHD, the OPEN L_Port is only allowed to transmit Link_Control frames (e.g., ACKs) and R_RDYs (i.e., Data frames may not be transmitted once DHD has been transmitted).

Table B.1 — Dynamic Half-Duplex

L_Port A (OPEN state)	Transmits	L_Port B (OPENED state)
Full-duplex L_Port (able to transmit and receive Data frames simultaneously)	OPNyx ==>	**Full-duplex L_Port** (able to transmit and receive Data frames simultaneously)
- Transmit n-1 Data frames.	R_RDYs ==>	
	frame(s) ==>	
	<== R_RDYs	- Transmit R_RDY and Link_Control frames (if any)
	<== frames	- Transmit Data frames
- Transmit last frame	frame(n) ==>	
If Login DHD is FALSE(0), transmit CLS.	CLS ==>	- CLS received, continue transmitting frames until Available_BB_Credit=0 or EE_Credit=0).
	<== frame(s)	
Loop is closed--next arbitrating L_Port wins Loop.	<== CLS	- Transmit CLS (a new arbitration cycle is required to transmit remaining frames).
- If Login DHD is TRUE(1), transmit DHD.		
	DHD ==>	- DHD received, continue transmitting frame; set DHD_RCV to TRUE(1).
Continue to transmit R_RDYs and Link_Control frames (if any)	<== frames	- Transmit n-1 Data frames
	R_RDYs ==>	- Transmit R_RDYs and Link_Control frames (if any)
	<==R_RDYs	
	<== frame(n)	- Transmit last frame
Transmit CLS to close Loop.	<== CLS	- Transmit CLS
	CLS ==>	- Loop is closed--next arbitrating L_Port wins Loop.
Full-duplex L_Port (able to transmit and receive Data frames simultaneously)	OPNyx ==>	**Half-duplex L_Port** (able to either transmit or receive Data frames in one direction only)
- Transmit n-1 Data frames.	R_RDYs ==>	
	frame(s) ==>	
	<== R_RDYs	- Transmit R_RDYs and Link_Control frames (if any)
- Transmit last frame	frame(n) ==>	
- If Login DHD is FALSE(0), transmit CLS.	CLS ==>	- CLS received
Loop is closed--next arbitrating L_Port wins Loop.	<== CLS	- Transmit CLS (a new arbitration cycle is required to transmit pending frames).
- If Login DHD is TRUE(1), transmit DHD.	DHD ==>	- DHD received, begin transmitting frames
	<== R_RDYs	- Transmit R_RDYs and Link_Control frames (if any)
	<== frames	- Transmit n-1 Data frames
Continue to transmit R_RDYs and Link_Control frames (if any)	R_RDYs ==>	
	<== frame(n)	- Transmit last frame
CLS received.	<== CLS	- Transmit CLS
Transmit CLS to close Loop.	CLS ==>	- CLS received--Loop is closed--next arbitrating L_Port wins Loop.

L_Port A (OPEN state)	Transmits	L_Port B (OPENED state)
Half-duplex L_Port (able to either transmit or receive Data frames in one direction only) - Transmit n-1 Data frames.	OPNyy ==> R_RDYs ==> frame(s) ==> <== R_RDYs	**Half-duplex L_Port** (able to either transmit or receive Data frames in one direction only) - Transmit R_RDYs and Link_Control frames (if any)
- Transmit last frame - If Login DHD is FALSE(0), transmit CLS. CLS received--Loop is closed--next arbitrating L_Port wins Loop.	frame(n) ==> CLS ==> <== CLS	 - CLS received. - Transmit CLS (a new arbitration cycle is required to transmit pending frames).
- If Login DHD is TRUE(1), transmit DHD.	DHD ==> <== R_RDYs <== frames	- DHD received, begin transmitting Data frames - Transmit R_RDYs and Link_Control frames (if any)
Continue to transmit R_RDYs and Link_Control frames (if any) CLS received Transmit CLS to close Loop.	R_RDYs ==> <== frame(n) <== CLS CLS ==>	- Transmit n-1 Data frames - Transmit last frame - Transmit CLS - CLS received--Loop is closed--next arbitrating L_Port wins Loop.
Half-duplex L_Port (able to either transmit or receive Data frames in one direction only) - Transmit n-1 Data frames.	OPNyy ==> R_RDYs ==> frame(s) ==> <== R_RDYs	**Full-duplex L_Port** (able to transmit and receive Data frames simultaneously, but since OPNyy received, cannot transmit Data frames) - Transmit R_RDYs and Link_Control frames (if any)
- Transmit last frame - If Login DHD is FALSE(0), transmit CLS. CLS received--Loop is closed--next arbitrating L_Port wins Loop.	frame(n) ==> CLS ==> <== CLS	 - CLS received. - Transmit CLS (a new arbitration cycle is required to transmit pending frames).
- If Login DHD is TRUE(1), transmit DHD.	DHD ==> <== R_RDYs <== frames	- DHD received, begin transmitting Data frames - Transmit R_RDYs and Link_Control frames (if any) - Transmit n-1 Data frames
Continue to transmit R_RDYs and Link_Control frames (if any) CLS received. Transmit CLS to close Loop.	R_RDYs ==> <== frame(n) <== CLS CLS ==>	- Transmit last frame - Transmit CLS - CLS received--Loop is closed--next arbitrating L_Port wins Loop.

NOTE — Table B.1 shows frame transfers based on R_RDY flow control. For dedicated Classes of service (e.g., Class 1), the R_RDYs would not be used (except on the first frame) and all flow control would be based on End-to-end-Credit.

FC-AL allows an L_Port in the OPEN state to use the TRANSFER state to make a connection to another L_Port without re-arbitrating. When DHD is transmitted by the OPEN L_Port, it normally would not transmit CLS. However, based on fairness rules (i.e., when to use the TRANSFER state), if ACCESS is TRUE(1), the OPEN L_Port may go to the TRANSFER state by transmitting CLS.

Annex C
(informative)

Multiple Loop examples

To provide better availability characteristics than is provided by a single Loop, there are at least two implementations supported by this standard as shown in figure C.1.

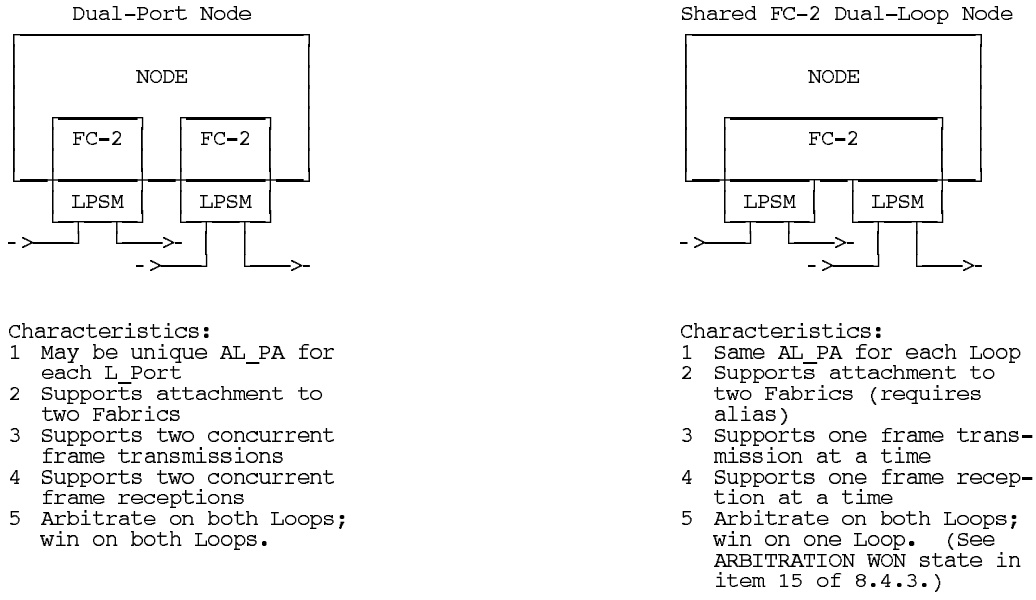


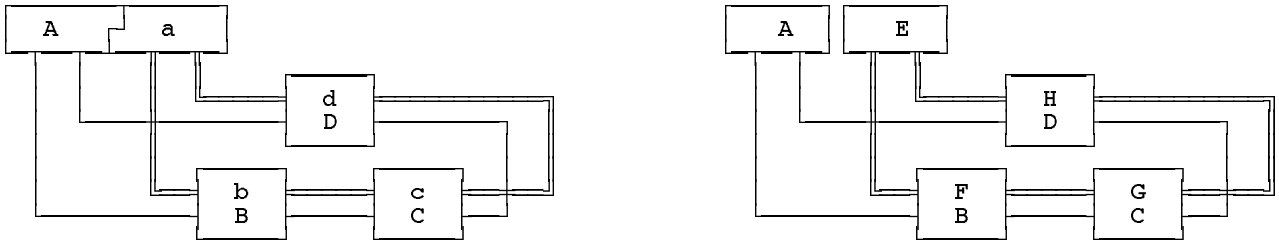
Figure C.1 — Multiple Loop examples

C.1 Dual-Port Node

The Dual-Port Node example (figure C.1(a)) shows two L_Ports and two Loops. The example may be extended to *n* L_Ports and *n* Loops. The AL_PA and native address identifier may have different values on each Loop. Each FC-2 and its LPSM have the operational characteristics of a single FC-2 and LPSM.

C.2 Shared FC-2 Dual-Loop Node

The shared FC-2 Dual-Loop Node example (figure C.1 (b)) shows one L_Port and two Loops. The example may be extended to *n* Loops. Figure C.2 shows two possible configurations using dual Loops. Figure C.2 (a) shows two Loops with only shared FC-2 Dual-Loop Nodes. Figure C.2 (b) shows a Dual-Port Node that could be two separate FL_Ports or two different NL_Ports (e.g., two controllers/initiators) attached to multiple shared FC-2 Dual-Loop Nodes. Operational characteristics are slightly different depending on which configuration is used.



a) b)

Figure C.2 — Configuration examples of multiple Loops

In figure C.2 (a), the AL_PA and native address identifier have the same values on each Loop. This configuration provides redundancy in case one Loop fails and allows two different L_Ports to use each Loop at the same time (e.g., 'A' can communicate with 'C' while 'b' is communicating with 'd'). However, only a single circuit may be established through Node (Aa) if Node (Aa) is an FL_Port.

In figure C.2 (b), the Loops may be attached to different FL_Ports (A and E) or a Dual_Port Node (AE) (as shown in figure C.1 (a)) and therefore, a different AL_PA and native address identifier (one for each Loop) should be used. For example, Node (BF) may have to recognize both AL_PA 'B' and 'F'. Recognition may be managed via an FC-PH alias (i.e., FC-2 recognizes multiple native address identifiers as if they are one). This configuration provides redundancy in case one Loop or one of the single L_Ports (e.g., 'A') fails. It also allows two circuits to be established into the Fabric (via L_Port 'A' and L_Port 'E') or two different L_Ports to use each Loop at the same time (e.g., 'A' can communicate with 'C' while 'G' is communicating with 'H').

Although the configuration in figure C.2 (a) would initialize correctly if only one Loop was used, it is probable that an L_Port does not know the configuration. Therefore, Loop Initialization may be performed as follows:

a) Transmit LIP on both Loops in the INITIALIZING state;

b) Receive LIP on both Loops and go to the OPEN-INIT state. In figure C.2 (a), the same node becomes the Loop master and only one AL_PA will be assigned by each LPSM; in figure C.2 (b), two different nodes may become the Loop master and two different AL_PAs may be assigned by each LPSM;

c) If there is one FL_Port, Fabric Login will result in one AL_PA for each Node; if there are two FL_Ports, Fabric Login may result in two different AL_PAs for each LPSM; or,

d) If a Node has two (or more) AL_PAs, it also has two (or more) native address identifiers. The shared FC-2 Dual-Loop Node may associate the two values via an alias.

The Node may ask to arbitrate on more than one Loop at the same time. Reasons for arbitrating on multiple Loops include:

— if one Loop is in use, arbitration could be won on the free Loop or

— if one Loop is not operational, arbitration could be won on the operational Loops.

When a Node uses multiple LPSMs to arbitrate, ARBx may be received simultaneously on any Loop. The L_Port must choose one of the LPSMs to go to the OPEN state. The remaining LPSMs are returned to the MONITORING state (via the OPEN and XMITTED CLOSE states) and are unavailable (non-participating) until the other LPSM returns to the MONITORING state (i.e., these LPSMs may not arbitrate, nor recognize an OPNy).

When a Node receives OPNy simultaneously at multiple LPSMs, the L_Port must choose one of the LPSMs to go to the OPENED state. The other LPSMs stay in the MONITORING state and are unavailable (non-participating) until the OPENED LPSM returns to the MONITORING state (i.e., these LPSMs may not arbitrate, nor recognize an OPNy).

There are a number of variations on these configurations depending on available receive buffers. The description above, assumes that there are no separate receive buffers for each LPSM.

C.3 Multiple Loop example for OFC

Figure C.3 shows how a dual Loop eliminates the timing problems when using Open Fibre Control (OFC) for laser safety. As shown, the OFC is between the driver-receiver pair of both Loop 1 and Loop 2. The dotted lines indicate how the data flows through each L_Port to complete the Loop circuits. Even though the lower block (identified by "Normal FC-PH Protocol Chip") implies one FC-2, the example would also work for two independent FC-2's.

If the link between L_Port A and L_Port B breaks, one implementation could allow for each of the transmitter/receiver pairs of the operating channel to complete one large Loop (i.e., Loop 1 and Loop 2 would collapse into a single large Loop). If the "Normal FC-PH Protocol Chip" implies two separate FC-2's, Loop Initialization allows the L_Ports of the combined Loops to obtain a new AL_PA (this is not required if there is only one FC-2).

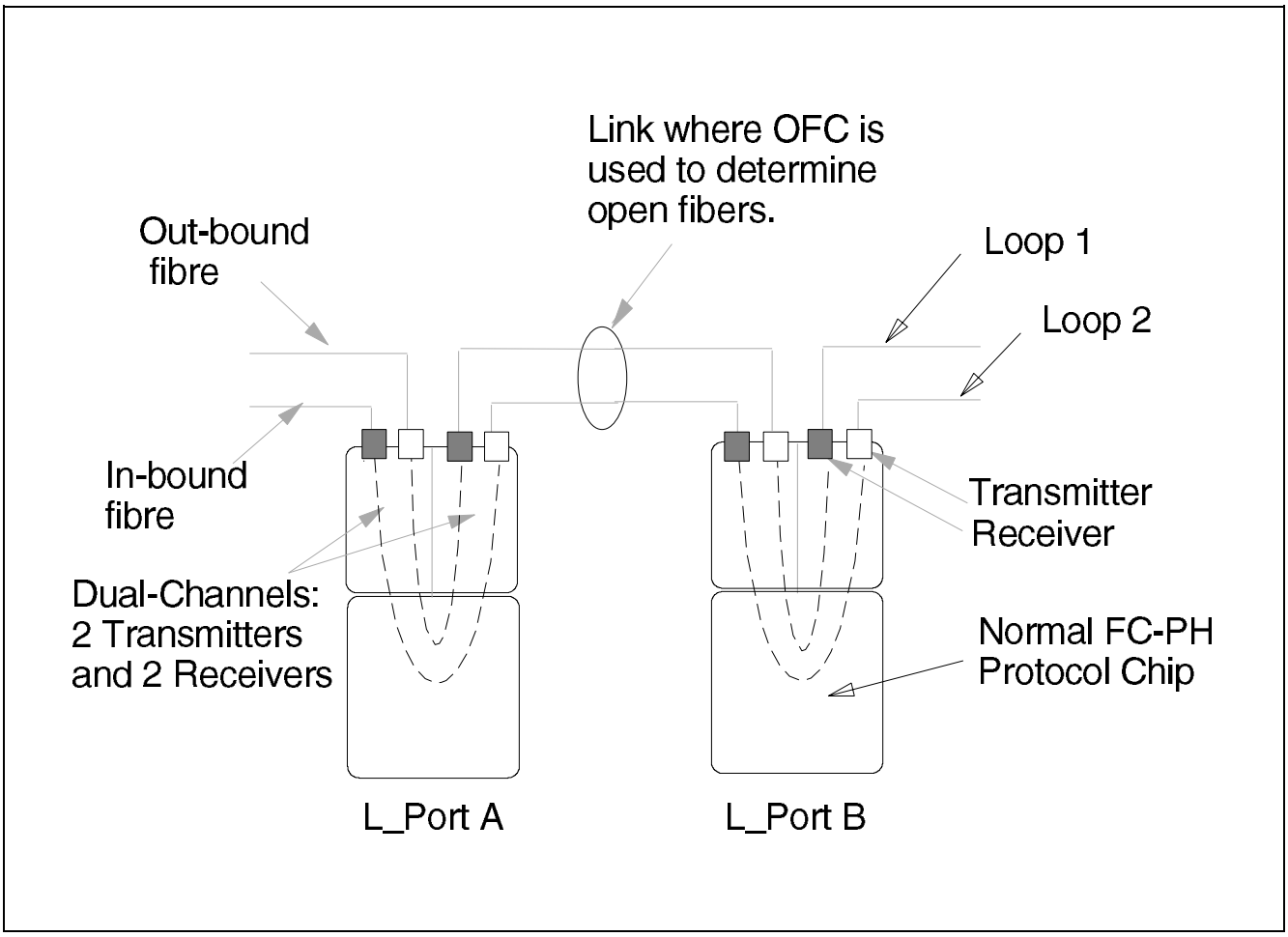


Figure C.3 — Multiple Loop example for OFC

Annex D
(informative)

Access unfairness

This annex describes how access unfairness might be used to improve Loop performance, and how access unfairness can be used to allow an NL_Port to reclaim ACK buffers when they become full.

D.1 Improving Loop performance

One possible use of the Loop is a serial version of a conventional single-Initiator parallel Small Computer System Interface (SCSI) bus. In this configuration, there is only one Initiator and many Target devices connected to the Loop. If all NL_Ports on the Loop, including the Initiator, follow the access fairness algorithm, then the Initiator may not be able to obtain sufficient Loop bandwidth to optimize overall performance by achieving a high level of parallelism among its Targets. A specific example is the situation where the Initiator transmits READ commands to all Targets. The Targets may take some time to locate the read data and then the Targets need to transmit the data to the Initiator.

Once a Target acquires the Loop and transmits its read data, it may be inactive unless it is given another command. If the Initiator follows the fairness algorithm, it will wait for all Targets that have read data pending to access the Loop, before it can access the Loop and transmit a Target a new command. To reduce the time that a Target is inactive, the Initiator may want to unfairly acquire the Loop and transmit the Target a new command. The Target can then start locating the data for the new command. Another performance enhancement would be to use full-duplex connections such that when the Target connects to the Initiator to transmit the requested data, the Initiator can transmit subsequent commands to that Target.

D.2 Emptying ACK buffers

With a Loop topology, a low-cost NL_Port may need to buffer outbound ACKs in Class 2.

One example occurs if a simple First-In-First-Out (FIFO) ACK buffer is used. The ACKs destined for the currently connected NL_Port cannot be sent because they are queued behind ACKs for other NL_Ports in the ACK FIFO.

Another example occurs in a full-duplex Loop circuit. If NL_Port A transmits a CLS to NL_Port B at the same time that NL_Port B transmits Data frames to NL_Port A, then NL_Port A must buffer ACKs for the Data frames that it receives after it has sent the CLS. This occurs because NL_Port A will receive Data frames after it has sent the CLS and made the transition to the XMITTED CLOSE state. NL_Port A cannot transmit frames (including ACKs) or R_RDYs in the XMITTED CLOSE state.

Alternatively, if the ACK buffer becomes full, NL_Port A may choose to unfairly arbitrate and acquire the Loop so that it can transmit the queued ACKs and reclaim its ACK buffer space. NL_Port A may use the TRANSFER state to speed up the process.

Annex E
(informative)

Half-duplex operation

This annex describes where half-duplex mode may be used to prevent ACK buffers from overflowing during Class 2 operation.

The operational characteristics of the Loop differ slightly from a point-to-point or from a Fabric topology. When an N_Port is directly connected to an F_Port, it can transmit an ACK frame whenever buffer-to-buffer credit is available. With the Loop, not only is Available_BB_Credit required, but the Loop must also have a circuit open with the correct L_Port before an ACK can be sent. At times, an NL_Port may need to buffer ACKs because it cannot access the Loop to transmit them.

Depending upon how ACK buffering is implemented, an NL_Port that is receiving Data frames may not be able to transmit the corresponding ACKs. If a simple FIFO is used to buffer ACKs, the ACKs for the currently connected NL_Port cannot be sent because they are queued behind ACKs for other NL_Ports in the ACK FIFO.

Another example where an NL_Port must buffer ACKs is in a full-duplex Loop circuit. If NL_Port A transmits a CLS to NL_Port B at the same time that NL_Port B transmits Data frames to NL_Port A, then NL_Port A must buffer ACKs for the Data frames that it receives after it has sent the CLS. This occurs because NL_Port A will receive Data frames after it has sent the CLS and made the transition to the XMITTED CLOSE state. NL_Port A cannot transmit frames (including ACKs) or R_RDYs in the XMITTED CLOSE state.

When an N_Port is connected directly to an F_Port, if it experiences a resource shortage to buffer ACKs, it will not transmit R_RDYs to the F_Port. The F_Port cannot transmit any frames to the N_Port without BB_Credit and therefore the N_Port will not owe EE_Credit and will not have to buffer the ACKs. The N_Port may continue to transmit ACKs and once sufficient ACK buffering is available the N_Port will transmit R_RDY to enable the F_Port to transmit frames.

On a Loop, an NL_Port has two techniques that can be used to reduce or prevent the receipt of Data frames and therefore, the number of ACKs it must buffer. The first technique is similar to the Fabric example above, where the NL_Port withholds R_RDYs when a circuit is opened. For example, an NL_Port can specify at Login that it has an BB_Credit of zero (0). When the NL_Port receives OPNy, it will not transmit any R_RDYs, preventing the opening NL_Port from transmitting any frames. The NL_Port will therefore not have to buffer ACKs.

A second technique, which an NL_Port can use to reduce or prevent the receipt of Data frames, is to establish a circuit in half-duplex mode. When the opened NL_Port receives the OPNyy, it is not allowed to transmit Data frames, only Link_Control frames. This guarantees that the NL_Port that established the circuit, will not receive Data frames and therefore will not be required to buffer ACKs.

Annex F
(informative)

BB_Credit and Available_BB_Credit management example

The following is an example implementation using BB_Credit and Available_BB_Credit. Assume two L_Ports, A and B, and that A arbitrated and won and is going to open B; full-duplex is used; and, both A and B have frames to transmit. L_Port A has sixteen receive buffers available and a BB_Credit Login value of two for L_Port B. L_Port B has eight receive buffers available and a BB_Credit Login value of one for L_Port A.

L_Port A:

1) looks up the BB_Credit Login value for B (two);

2) checks to see how many receive buffers it has available (sixteen);

3) transmits OPN(B,A), two Fill Words and one R_RDY and three Fill Words, followed by two frames (BB_Credit Login value for B). Note that had BB_Credit been zero (0), no frames could have been sent by A. The remaining fifteen R_RDYS are transmitted after the first frame;

4) receives and counts the R_RDYs sent by B (eight). Once L_Port A has received and discarded two R_RDYs (which are for the frames already shipped against BB_Credit in 3 above), L_Port A has an Available_BB_Credit of six that it may use to transmit up to six additional frames;

5) transmits one frame for each Available_BB_Credit;

6) receives R_RDYs sent by B and increments Available_BB_Credit;

7) receives the number of frames sent by B into the receive buffer(s);

8) transmits one R_RDY for each receive buffer that has been made available

9) repeats steps 5 through 8 until all frames have been sent;

10) transmits CLS;

11) continues to receive frames from B, but transmits no R_RDYs or frames; and,

12) receives CLS and closes its end of the Loop.

L_Port B:

1) receives OPN(B,A) and opens the Loop;

2) looks up the BB_Credit for A (one);

3) checks to see how many receive buffers it has available (eight);

4) transmits two Fill Words and one R_RDY and three Fill Words, followed by one frame (BB_Credit Login value for A). Note that had BB_Credit been zero (0), no frames could have been sent by B. The remaining seven R_RDYs are transmitted after the first frame. Once L_Port B has received and discarded one R_RDY (which is for the frame already shipped against BB_Credit) and counted the other R_RDYs from A, L_Port B has an Available_BB_Credit of fifteen that it may use to transmit up to fifteen additional frames;

5) receives and counts the R_RDYs sent by A by increasing Available_BB_Credit by one for each R_RDY. L_Port B can now transmit an additional frame for each R_RDY that it has received;

6) receives the number of frames sent by A into the receive buffer(s);

7) transmits an R_RDY for each receive buffer that has been made available;

8) repeats steps 5 through 7 until the CLS is received from A; and,

9) may continue to transmit frames until Available_BB_Credit or EE_Credit is exhausted, followed by a CLS. When the CLS is sent, L_Port B closes its end of the Loop.

There are several variations on the previous example.

1) Data frame transfer is only from A to B even though OPN(B,A) (full-duplex) is used. L_Port A transmits one R_RDY followed by the number of frames represented by the BB_Credit Login value. In this case, B has no Data frames to transmit, but transmits one R_RDY for each available receive buffer and Link_Control frames (e.g., ACKs) to A. Note that B may limit the number of frames that A can transmit by transmitting one R_RDY for each available receive buffer, followed by CLS. Once L_Port A has received the CLS, it can then only transmit frames until its Available_BB_Credit is exhausted before it must close its end of the Loop;

2) BB_Credit is zero (0) on both ends. In this case, neither A nor B can transmit any frames until at least one R_RDY is received. For each R_RDY received, a frame may be sent. Note that when BB_Credit is zero (0), a Loop turn-around delay is required at A before transmitting the first (and possibly the only) frame. By guaranteeing a minimum number of receive buffers (as indicated by BB_Credit), this turn-around delay may be eliminated;

3) L_Port A transmits an OPN(B,A) (full-duplex), followed by at least one R_RDY, followed by two frames (the BB_Credit Login value for L_Port B). L_Port B does not look up the BB_Credit for A, and transmits at least one R_RDY (one for each available receive buffer). L_Port B waits for the first R_RDY from A. When at least one R_RDY is received (i.e., Available_BB_Credit is one (1)), B can transmit one frame;

4) L_Port A transmits an OPN(B,B) (half-duplex). In this case, L_Port B cannot identify A and must wait for the first frame from A to transmit any frames (note: since this is a half-duplex OPNyy, no Data frames may be transmitted by B). Once a frame is received, the low-order byte of the S_ID is the AL_PA of A. B can then establish the BB_Credit for A. If B is using a minimum Loop value for BB_Credit, the AL_PA of A is not required; and,

5) L_Port A transmits an OPN(B,B) (half-duplex). In this case, L_Port B must wait for the first R_RDY from A. Once at least one R_RDY is received (i.e., Available_BB_Credit is one (1)), B can transmit one Link_ Control frame to A.

Annex G
(informative)

Clock skew smoothing function

This annex describes one implementation of a smoothing algorithm that will maintain the inter-frame gap to a minimum of six words (Fill Words and R_RDY Primitive Signals) as specified in ANSI X3.230, FC-PH.

NOTE — This section is provided as an example of an implementation that can guarantee, with a very high probability, the size of the repeated inter-frame gap. If an implementation chooses to repeat the bit stream synchronously (i.e., the retransmitted output frequency is locked to the received data), then there would be no need for an elasticity buffer and smoothing function. This section is only relevant to those implementations that re-time the repeated output with a different frequency source (i.e., local clock).

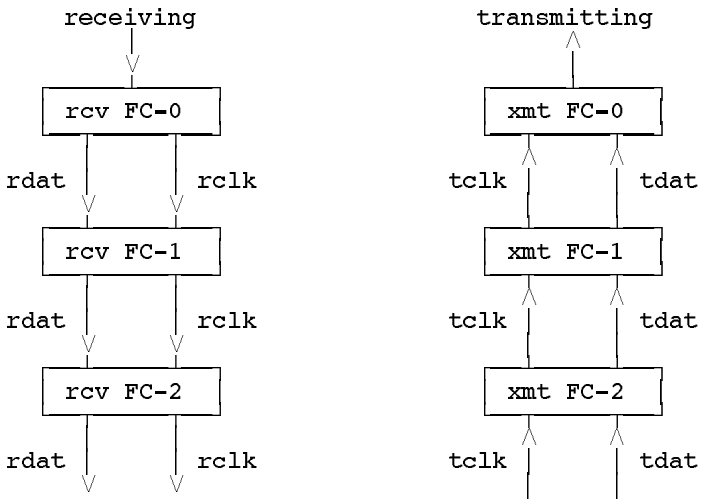
G.1 Smoothing function requirement

In a Loop, transmitter and receiver clocks may be mismatched. To avoid overrunning the transmitter, elasticity buffers (i.e., speed matching buffers) are used to buffer the received data. The size of the elasticity buffer is calculated to allow for maximum phase and frequency mismatch between the transmitter and receiver for the length of the largest frame size allowed on the Loop. The objective is to keep the size of the elasticity buffer to a minimum. This will ensure minimum node latency and maximum Loop performance. To achieve this objective, an elasticity buffer should center when a SOF is detected and should have enough depth on either side to accommodate both fast or slow clocks without losing data for an entire frame. Once the EOF has been detected, no more writes to the elasticity buffer are made until another SOF is detected and once again the elasticity buffer is recentered. This is the area of operation that requires a minimum of inter-frame gap to operate properly. If the inter-frame gap is too short (i.e., less than the minimum allowed number of Fill Words) then the elasticity buffer recenters on a new SOF. If the data in the elasticity buffer has not been processed (read out), then it is lost during the recentering operation (preparing for next frame).

Fill Words are transmitted after the EOF has been transmitted and until the SOF from the next frame has been processed out of the elasticity buffer. The inter-frame gap is continuously changing due to this action of the elasticity buffers in the Loop (i.e., a slow node in the MONITORING (repeat) state receiving frames from a fast node would delete Fill Words or MRKtx between frames as it repeats them, and vice-versa for Fill Word insertion). In a large Loop, after a serial stream has passed through a number of nodes (all at different crystal tolerances), this action could reduce the inter-frame gap to a point where data integrity is affected.

G.2 Smoothing function elasticity buffer

The majority of the logic in each FC-AL Port can be designed to operate synchronously or asynchronously to the received data rate. If the receive data path logic has a reference frequency source located within the Port, then it is said to be asynchronous to the received data rate. If the receive data path logic has a reference frequency that is derived from the received serial data stream, then it is said to be synchronous to the received data rate. (See figure G.1.)



NOTE — In repeating mode, tclk = filtered(rclk)

Figure G.1 — Example of a synchronous receiver design

In an asynchronous receiving logic, each received word must be synchronized to a slightly different frequency. Since the rate of arrival is different from the rate the words are transmitted, the elasticity buffer guarantees the proper operation of the frequency matching process and eliminates the possibility of any data loss. (See figure G.2.)

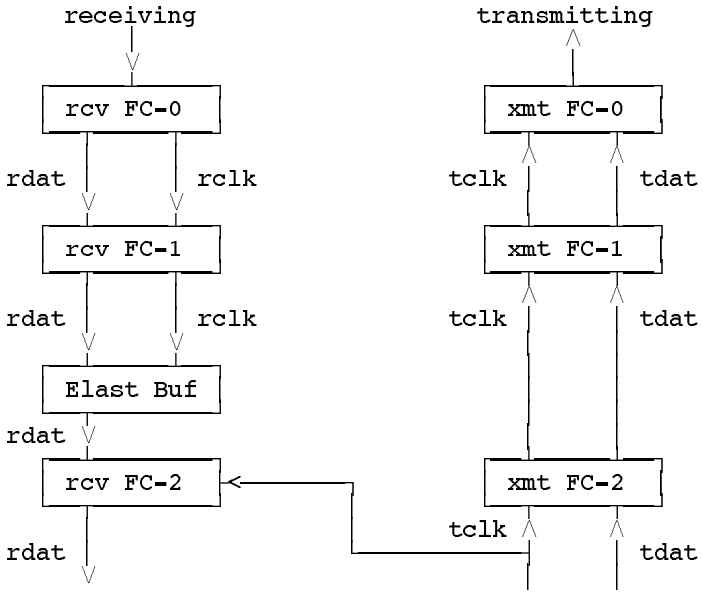


Figure G.2 — Example of an asynchronous receiver design

Assuming a worst case frequency mismatch between two connected Ports (i.e., transmitter at f+(100ppm)*f and receiver at f-(100ppm)*f), the net elasticity needed for a maximum size frame is:

2172 Bytes * 200 ppm * 10/8 code = 4.4 code bits.

NOTE — 2172 is the maximum repetitive pattern: 2112 (data field) + 24 (FC header) + 12 (SOF, EOF, and CRC) + 24 (six Fill Words).

The elasticity can be implemented as a first-in-first-out (FIFO) device with the input coming from the received data and the output going to the receiving FC-2 logic. At the beginning of each frame, there must be enough (at least +/-4.3 code bits) elasticity in the FIFO, so that by the end of a maximum size frame there would be no FIFO underflow or overflow conditions.

G.3 Smoothing function description

The smoothing function provides a method to maintain the inter-frame gap at a selected value (at least six words) by:

— deleting a Fill Word from inter-frame gaps with greater than six words or

— inserting a Fill Word in inter-frame gaps that have less than six words.

This smoothing function absorbs surplus Fill Words from longer inter-frame gaps and redistributes then into shorter inter-frame gaps, thus significantly reducing the variance of inter-frame gaps during long burst (streaming) of frames or cycles.

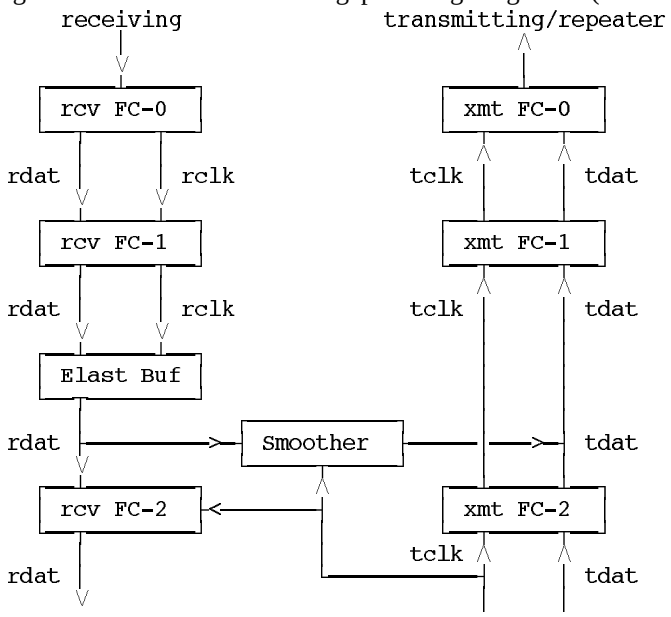


Figure G.3 — Example of an asynchronous receiver with smoother

Given that the inter-frame gap consists of Fill Words (in the absence of noise), it is possible to relax some constraints on inter-frame gap processing with minimal impact on reliability. Specifically, during inter-frame gap processing the smoother function:

— is not required to insert Fill Words into an inter-frame gap except after two (2) consecutive Fill Words are received and

— must not delete non-Fill Words (except MRKtx) from an inter-frame gap longer than the high-threshold, so that previously inserted Fill Words may be reclaimed.

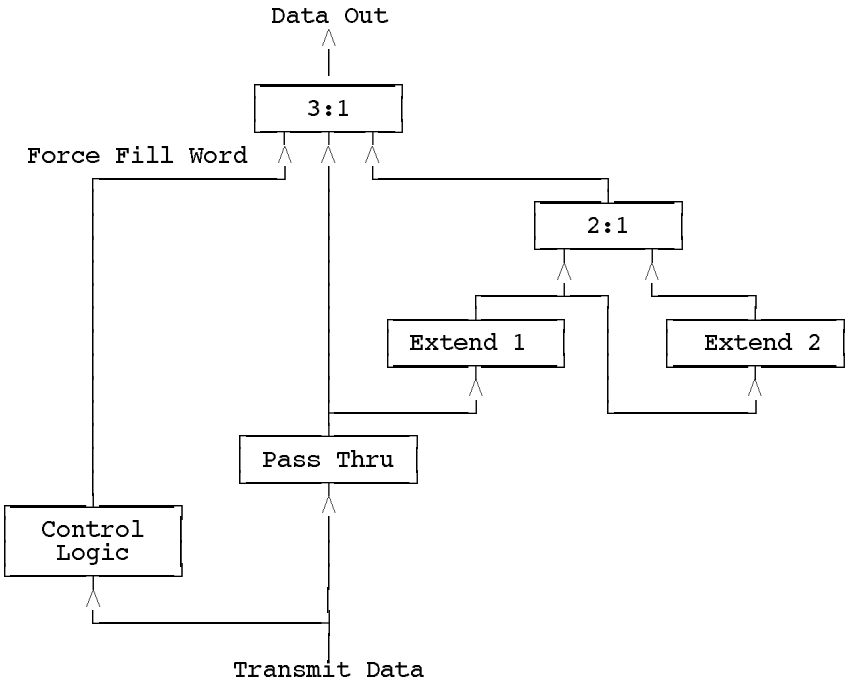


Figure G.4 — Example of smoother implementation

The smoothing function state diagram is shown in figure G.5:

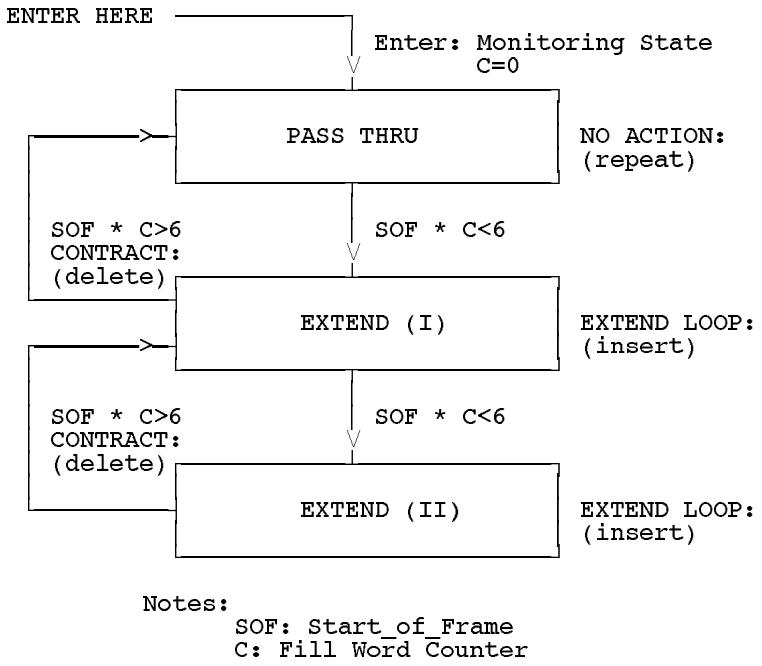


Figure G.5 — Smoother state diagram

Annex H
(informative)

Mark Synchronization examples

This annex describes two examples of how the Mark (MRKtx) Primitive Signal may be used on a Loop. Since some states do not retransmit MRKtx, the only way to guarantee that the originator receives the transmitted MRKtx is for the originator to be in the OPEN state and for all other L_Ports to be in the MONITORING state.

H.1 Clock synchronization

When the type of mark (MK_TP) is clock synchronization (e.g., hex '00'), the Mark Primitive Signal may be used to synchronize clocks between a number of processors. Through configuration or implementation, one processor is assigned the task of providing a Master clock. It is the responsibility of this processor to generate enough MRKtx Primitive Signals to keep the other processors within a prespecified clock tolerance.

The processor with the Master clock transmits one MRKtx (with t = hex '00' and x = its AL_PA) instead of a Fill Word for each REQ(mark as tx). Each recipient of the MRKtx checks the AL_PA to synchronize on the correct Master clock (since the AL_PA is used to identify the originator, this allows multiple Master clock originators). If the AL_PA matches the one being used for synchronization, the receiving processor adjusts (if necessary) its clock and retransmits the MRKtx. If the MRKtx is returned to the originator, the originator replaces it with the current Fill Word.

Because the MRKtx may not be inserted onto the Loop except during normal Fill Word transmission, it is possible that a MRKtx may not be originated or retransmitted. If the processors can accept a missing MRKtx, the MRKtx provides a low-cost method (does not require a separate clock synchronization interface) for keeping clocks synchronized. To obtain an initial clock value, the ANSI X3.230, FC-PH defined Time Server at well-known address hex 'FFFFFB' may be used. Once every processor has this initial clock value, the MRKtx may be used to maintain clock synchronization. The Time Server function may be provided by an F/NL_Port in the absence of a Fabric.

If the originator of the MRKtx receives the MRKtx, it may calculate the latency for the MRKtx to traverse the Loop. If this latency is greater than the clock synchronization tolerance, a system administrator may be informed that the MRKtx is unpredictable in the configured environment.

H.2 Disk spindle synchronization

When the type of mark (MK_TP) is disk spindle synchronization (e.g., hex '01'), the Mark Primitive Signal may be used to synchronize disk spindles between a number of disk drives. Through configuration or implementation, one disk drive is assigned the task of providing a Master clock. It is the responsibility of this disk drive to generate enough MRKtx Primitive Signals to keep the other disk drives within a prespecified spindle synchronization tolerance.

The disk drive with the Master clock transmits one MRKtx (with t = hex '01' and x = its AL_PA) instead of a Fill Word for each REQ(mark as tx). The recipient of the MRKtx checks the AL_PA to synchronize on the correct Master disk spindle (since the AL_PA is used to identify the originator, this allows multiple Master spindle synchronization originators). If the AL_PA matches the one being used for synchronization, the receiving disk drive adjusts (if necessary) its spindle motor and retransmits the MRKtx. If the MRKtx is returned to the originator, the originator replaces it with the current Fill Word.

Because the MRKtx may not be inserted onto the Loop except during normal Fill Word transmission, it is possible that a MRKtx may not be originated or retransmitted. If the disk drives can accept a missing MRKtx, the MRKtx provides a low-cost method (does not require a separate spindle synchronization interface) for keeping disk spindles synchronized.

If the originator of the MRKtx receives the MRKtx, it may calculate the latency for the MRKtx to traverse the Loop. If this latency is greater than the disk spindle synchronization tolerance, a system administer may be informed that the MRKtx is unpredictable in the configured environment.

Annex I
(informative)

Bypass Circuit example and usage

This annex describes a Bypass Circuit which may be used to keep a Loop operating when an L_Port location is physically removed or not populated; L_Ports are powered-off; or, a failing L_Port is present. A Bypass Circuit provides the means to route the serial channel signal past an L_Port. Also described are the L_Port Bypass/Enable (LPB/LPE) Primitive Sequences. The main purpose of these Primitive Sequences is to physically control the Bypass Circuit (if present) and logically control the L_Port (i.e., the LPSM is forced into and held in the MONITORING state). Since LPB and LPE are Primitive Sequences, they are usually transmitted for AL_TIME or until the transmitted Primitive Sequence is received.

I.1 Bypass Circuit

Figure I.1 shows an example Bypass Circuit. The input from the previous L_Port, *n*-1, feeds a multiplexer (MUX) and the local L_Port. The other input to the multiplexer is from the local L_Port. A select signal determines whether the input from L_Port *n*-1 or the input from the local L_Port is transmitted to the next L_Port, *n*+1. The Bypass Circuit is an asynchronous switch (i.e., when it switches, it may cause a loss of synchronization at the next L_Port). To avoid unnecessary reinitializations and error counters to overflow, L_Ports and Bypass Circuits should be used which avoid counting this loss of synchronization as an error and going to the INITIALIZATION state.

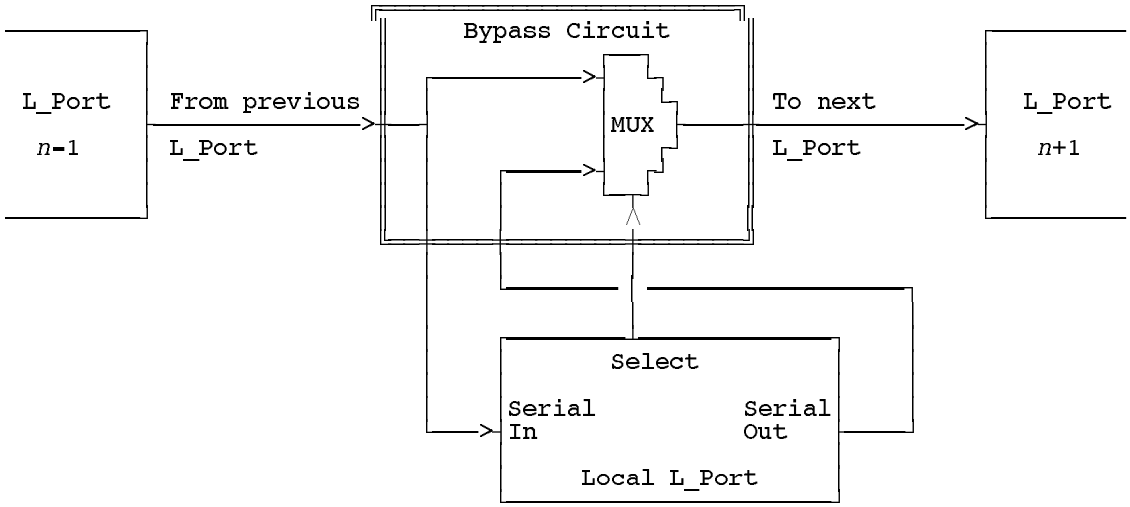


Figure I.1 — Example Bypass Circuit

I.1.1 Default bypass

The Bypass Circuit for an unpopulated location or a powered-off L_Port defaults to the Bypass Circuit being set (i.e., the input from *n*-1 passes through the multiplexer to *n*+1).

I.1.2 Power-on reset bypass

At power-on, an L_Port leaves the Bypass Circuit set and enters the MONITORING state in non-participating mode. This allows the Loop to continue to function while the Port performs a self-test. When the L_Port is ready to enter the participating mode, the L_Port resets it's Bypass Circuit and enters the INITIALIZING state.

I.2 Using a Bypass Circuit

Any L_Port may accept the role of Loop manager to execute diagnostics and to recover a failing Loop. The selection criteria of a Loop manager should include the ability to report failures to an operator or system log. A "Loop manager" in the context of this discussion is an L_Port that has the ability to diagnose a Loop (i.e., uses LPB and LPE to bypass and enable other L_Ports).

I.2.1 Diagnostic Test of the Bypass Circuit

Loop Initialization must be completed before the Bypass Circuit may be tested. L_Ports must be in the participating mode (i.e., have an AL_PA) for the test to be effective.

The Loop manager arbitrates for the Loop; transmits an OPNyy (where y is the AL_PA of the Loop manager); and, transmits the L_Port Bypass Primitive Sequence (LPByx, where y is the AL_PA of the L_Port under test and x is its AL_PA) until the Primitive Sequence is received. This allows any receiver, affected by an L_Port switching out of the Loop, to synchronize to the new input. The Loop manager removes all LPBs that it originated.

In order to verify that the Bypass Circuit is present and operating, the Loop manager may: transmit CLS and enter the TRANSFER state; when CLS is received, transmit OPNyx (where y is the AL_PA of the L_Port under test). If the OPNyx is received by the Loop manager, the Bypass Circuit is functioning normally.

The Loop manager completes the test by transmitting the L_Port Enable Primitive Sequence (LPEyx where y is the AL_PA of the bypassed L_Port and x is it's AL_PA) until the Primitive Sequence is received. The Loop manager removes all LPEs that it originated. In order to verify that the L_Port is no longer bypassed the Loop manager may: transmit CLS and enter the TRANSFER state; when CLS is received, transmit OPNyx (where y is the AL_PA of the L_Port under test). If the OPNyx is not received by the Loop manager within AL_TIME, the Bypass Circuit has been reset and is functioning normally. The Loop manager may then transmit CLS and wait for the CLS to be returned. If other Bypass Circuit s are to be tested, the Loop manager may use the TRANSFER state until all AL_PAs have been tested.

If at any time during the above test, the Loop manager receives a LIP, the AL_PA of the bypassed L_Port has been relinquished. The Loop manager then can only use LPEfx to enable a previously bypassed L_Port.

I.2.2 Recovery from Loop Failure

If an L_Port detects a Loop Failure at its receiver for R_T_TOV, it may use the following recovery procedure. Waiting for R_T_TOV, allows recovery from transient conditions.

After an R_T_TOV time-out, the L_Port may perform an optional loop-back self test. If the loop-back test fails, the L_Port may request to be bypassed (REQ(bypass L_Port)) to allow the Loop to recover. If the loop-back test passes, the L_Port requests to go to the INITIALIZATION state where it transmits an error LIP (see 7.8.2 or 7.8.4) for up to two (2) AL_TIMEs or until LIP is received.

If LIP is received, the L_Port goes to the OPEN-INIT state and transmits at least twelve (12) of the received LIPs (see 7.8.1 or 7.8.3).

If LIP is not received within two (2) AL_TIMEs, the L_Port transmits LPByx to bypass the failing L_Port (identified by the y value). The Loop manager may use the AL_PA position map from the most recent Loop Initialization to identify the failing L_Port (it is the L_Port adjacent to the L_Port that detects the Loop Failure). If this AL_PA position map is not available, the Loop manager may attempt all valid AL_PAs (excluding its own), bypassing all L_Ports until the failing L_Port is identified. The Loop manager may also transmit LPBfx to bypass all L_Ports (even those that do not have a valid AL_PA). The Loop manager transmits each LPByx for up to two (2) AL_TIMEs or until the Primitive Sequence is received to allow any receiver affected by a Port switching out of the Loop to synchronize to the new input. Once the failing L_Port has been bypassed, if any other L_Ports had been bypassed, they should be reenabled with LPEyx. If the Loop failure occurs during a time when the failing L_Port does not have a valid AL_PA, manual intervention may be required to find the failing L_Port or LPBfx may be used to bypass all L_Ports and if successful, one L_Port at a time may be reenabled with LPByx.

I.2.3 Power-on with a failing L_Port

An L_Port that is unable to pass its self-test does not reset its Bypass Circuit. If an L_Port has an AL_PA which it previously saved in non-volatile storage, it follows the same procedure as if the Loop failed after being operational. (See I.2.2.)

In a Loop without valid AL_PAs, recovery of the Loop may require manual intervention (e.g., physically removing one L_Port after another until the failing L_Port is identified), unless the failing L_Port can initiate a bypass (REQ(bypass L_Port)).

I.2.4 Reconfiguring a Loop with LPB and LPE

A Loop manager may elect to use the Bypass Circuit to physically switch participating L_Ports in and out of the Loop. When an L_Port is enabled on the Loop, the Loop manager should begin Loop Initialization to ensure that there are no AL_PA conflicts.

Annex J
(informative)

Public L_Ports and Private NL_Ports on a Loop

This annex describes how Public L_Ports and Private NL_Ports may be used on a Public Loop. Figure J.1 shows an example of such a configuration. Two advantages of connecting L_Ports in this fashion are: security (Private NL_Ports may not be addressed by Ports not on the Loop) and the Private NL_Ports may be lower cost.

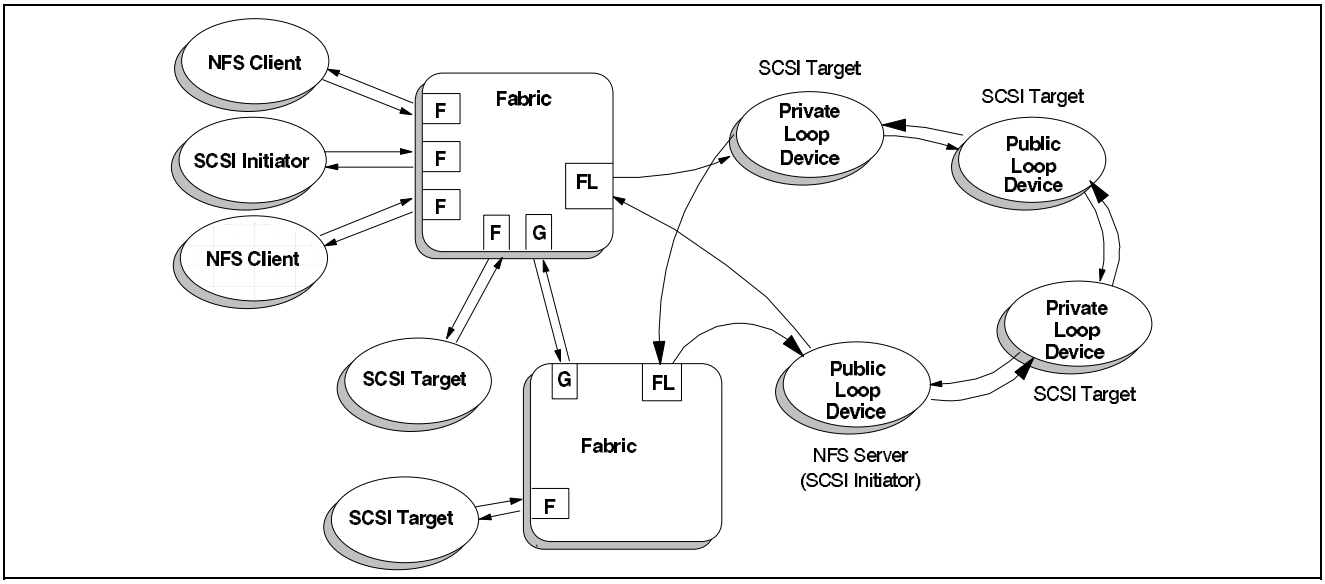


Figure J.1 — Public L_Ports and Private NL_Ports on a Loop

In this example, an NFS (Network File System) client on the left transmits an NFS command through the Fabric to the NFS server (the NFS client only knows that the NFS server has access to the requested data, but does not know the location of the data). The NFS server is also a SCSI (Small Computer System Interface) initiator and it knows which SCSI target has the data. A SCSI command is sent by the NFS server (SCSI initiator) to any of the SCSI targets on the Loop. When the SCSI target has the requested data, it transmits the data to the SCSI initiator, which in turn transmits it via an NFS response to the NFS client.

As shown in this example, Private NL_Ports (SCSI targets) do not communicate with any Port not on the Loop, including the FL_Port. However, the Public NL_Port (SCSI target) may be addressed by both the NFS server (SCSI initiator) and the SCSI initiator on the other side of the Fabric.

Annex K

(informative)

Assigned Loop Identifier

This annex shows in table K.1 how a 7-bit Loop Identifier (e.g., a switch) may be used to represent the Hard Assigned AL_PA as used in clause 10.4. If there are no conflicts or an attached Fabric does not reassign the AL_PA, the value represented by this Assigned Loop Identifier will be the AL_PA of the L_Port. (See also table 15.)

Table K.1 — Assigned Loop Identifier

AL_PA (hex)	Switch Setting (hex)	(dec)	AL_PA (hex)	Switch Setting (hex)	(dec)	AL_PA (hex)	Switch Setting (hex)	(dec)
EF	00	0	A3	2B	43	4D	56	86
E8	01	1	9F	2C	44	4C	57	87
E4	02	2	9E	2D	45	4B	58	88
E2	03	3	9D	2E	46	4A	59	89
E1	04	4	9B	2F	47	49	5A	90
E0	05	5	98	30	48	47	5B	91
DC	06	6	97	31	49	46	5C	92
DA	07	7	90	32	50	45	5D	93
D9	08	8	8F	33	51	43	5E	94
D6	09	9	88	34	52	3C	5F	95
D5	0A	10	84	35	53	3A	60	96
D4	0B	11	82	36	54	39	61	97
D3	0C	12	81	37	55	36	62	98
D2	0D	13	80	38	56	35	63	99
D1	0E	14	7C	39	57	34	64	100
CE	0F	15	7A	3A	58	33	65	101
CD	10	16	79	3B	59	32	66	102
CC	11	17	76	3C	60	31	67	103
CB	12	18	75	3D	61	2E	68	104
CA	13	19	74	3E	62	2D	69	105
C9	14	20	73	3F	63	2C	6A	106
C7	15	21	72	40	64	2B	6B	107
C6	16	22	71	41	65	2A	6C	108
C5	17	23	6E	42	66	29	6D	109
C3	18	24	6D	43	67	27	6E	110
BC	19	25	6C	44	68	26	6F	111
BA	1A	26	6B	45	69	25	70	112
B9	1B	27	6A	46	70	23	71	113
B6	1C	28	69	47	71	1F	72	114
B5	1D	29	67	48	72	1E	73	115
B4	1E	30	66	49	73	1D	74	116
B3	1F	31	65	4A	74	1B	75	117
B2	20	32	63	4B	75	18	76	118
B1	21	33	5C	4C	76	17	77	119
AE	22	34	5A	4D	77	10	78	120
AD	23	35	59	4E	78	0F	79	121
AC	24	36	56	4F	79	08	7A	122
AB	25	37	55	50	80	04	7B	123
AA	26	38	54	51	81	02	7C	124
A9	27	39	53	52	82	01	7D	125
A7	28	40	52	53	83			
A6	29	41	51	54	84	00	7E	126
A5	2A	42	4E	55	85	--	7F	127

Note — The values are intentionally from lowest to highest priority.
AL_PA = 00 is reserved for an FL_Port; '--' is not available.

Annex L
(informative)

Selective replicate for parallel query acceleration

This annex describes a relational database example that benefits from the selective replicate capability of FC-AL. Because queries are ad hoc, it is not known in advance which Ports will participate in a given multicast group, and the group can change with each query. This annex illustrates how OPNyr is preferable to using traditional multicast groups, which must be set up in advance. OPNyr significantly speeds up the execution of parallel queries.

The examples show a sort-merge join which is a technique employed by several database vendors. An example of a hypothetical parallel query engine is provided in clause L.2 and a specific example of a query is provided in clause L.3.

L.1 Parallel query technology

Parallel query is a technique for significantly reducing the response time of complex queries against very large databases. The basic technique divides the query among multiple CPUs, where each CPU applies the query against a partitioned, disjoint subset of the database tables selected in the query. Most parallel query algorithms focus on joins, where row pieces from one or more tables are combined on some matching attribute.

L.2 Shared disk cluster

A cluster composed of multiple hosts accessing a large shared disk pool is illustrated in figure L.1. There are *n* database servers accessing a shared database striped across all drives that are attached via one or more FC-AL Loops. Every server has direct access to any partition of the database on the shared disk pool. The FC-AL Loops serve a dual role in the cluster. First, they function as a high speed disk channel for SCSI traffic between servers and disk. Second, they function as a high bandwidth, low-latency Port-to-Port interconnect for IP traffic between servers. As this example shows, many database blocks are passed directly between servers during the parallel query.

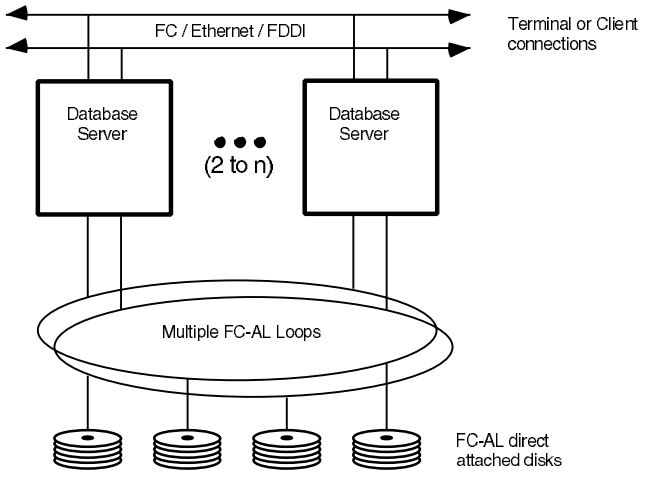


Figure L.1 — FC-AL parallel query server

L.3 Parallel query example

To illustrate a complex query typical of a direct marketing application often found in DSS (Decision Support Systems) or Data Warehousing, the following query is used as an example of how a parallel query could be executed to take advantage of selective replicate on the above configuration:

```
1    Select customer, address, num_purchases
2        From R, S
3        Where R.a = S.b
4        and num_purchases > 10
5        and (area code = 415
6            or area code = 408
7            or area code = 510)
```

This is a join of relations (database tables) R and S that satisfy the matching attribute in line 3. The matching attribute (R.a and S.b) is the customer ID. The query is intended to find all customers in the San Francisco Bay Area that have made a large number of purchases (more than 10). Relation S is the total worldwide customer population. Relation R is all purchases in California for the past three months. Relation S is many times larger than relation R, since R will only contain the subset of customers who have made purchases in the San Francisco Bay Area over the last three months. Tuples (records) from relation R are qualified by line 4, while tuples from relation S are qualified by lines 5 to 7. Applying qualifiers to a relation are known as a *projection* in database language. A projection reduces the number of tuple candidates that must be examined to determine if they match the join criteria in line 3.

Relations R and S are striped across all disk drives, D, in the cluster. Assume that there are *m* hosts available to participate in the query, where $m <= n$.

When the query is submitted to the cluster, a processor (e.g., B) is selected as the query coordinator. The query coordinator determines how the query will be executed and elects the other processors to participate in the parallel query. The decision as to which processor and how many processors will participate is made at run time. It is based on such factors as the load at each individual processors, the type of query being submitted, and the privilege of the user. For example, Tony CEO may be allowed to use all processors while Joe Clerk may only use 4 processors. The *m* participating processors form a multicast group that is dynamically created when the query is parsed. The query coordinator determines that relation R is too small to parallelize, since the overhead of parallelism will outweigh any speedup.

The query plan generated by the coordinator is illustrated by the following pseudo-code:

```
        CPU B (query coordinator)
                notify all participants 1 to m-1
1               multicast query plan            // includes split table
                scan R                          // read all tuples in R
                apply predicate to R -> R'
                sort R' -> R"                   // sort on joining attribute R.a
2               multicast R"
                wait for "scan S done" messages 1 to m-1
3               multicast "do join" messages" 1 to m-1
                wait for "join done" messages 1 to m-1
                done!
        CPU 1 to m-1 (query slaves)
                receive query plan
                scan S / (m-1) -> S'
                                // partitioned on tuple ID into m-1 buckets
                for each tuple
                        apply predicate
                        hash lookup in split table -> I
                                // hashed on phone # into m-1 buckets
                        if I <> me
                                transmit to CPU I
                transmit "scan S done" message to B
                when "do join" message received
                        sort S'   -> S”     // sort on joining attribute S.a
                while not at end of S"
                        for each tuple in R"
                                lookup R".a in S"
                                        if match write to join result
                transmit "join done" message to B
                done!
```

The selective replicate FC-AL Primitive Signal, OPNyr, is used by the query coordinator in lines 1 to 3 above. In line 1, the query plan must be sent to all participants. It tells each CPU which partition of relation S it shall scan, and the hash function and split table values to use for each bucket. Line 2 is used to transmit the sorted relation R" to all participants. Line 3 is used to synchronize the completion of the scan phase with the start of the join phase.

This example demonstrates the utility of the selective replicate Primitive Signal for different uses. It can be employed to synchronize multiple CPUs with control messages (1 and 3). More importantly, it can be used to replicate large blocks of data between coordinating CPUs (2). In addition, the low overhead of forming constantly changing multicast groups allows efficient schedulers to determine the appropriate level of parallelism for each task at run time.

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