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Information processing systems — Fibre Distributed Data Interface (FDDI) —

Part 1 :
Token Ring Physical Layer Protocol (PHY)

Systèmes de traitement de l'information — Interface de données distribuées sur fibre (FDDI) —

Partie 1 : Protocole de la couche physique de l'anneau à jeton

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 9314-1 was prepared by Technical Committee ISO/TC 97, *Information processing systems.*

ISO 9314 consists of the following parts, under the general title *Information processing systems — Fibre Distributed Data Interface (FDDI)*:

— *Part 1: Token Ring Physical Layer Protocol (PHY)*

— *Part 2: Token Ring Media Access Control (MAC)*

— *Part 3: Token Ring Physical Layer, Medium Dependent (PMD)*

Introduction

This part of ISO 9314 on the FDDI physical layer protocol is intended for use in a high-performance multistation network. This protocol is designed to be effective at 100 Mbit/s using a Token ring architecture and fibre optics as the transmission medium over distances of several kilometers in extent.

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Information processing systems — Fibre Distributed Data Interface (FDDI) —

Part 1 : Token Ring Physical Layer Protocol (PHY)

1 Scope

This part of ISO 9314 specifies the Physical Layer Protocol (PHY), the upper sublayer of the Physical Layer, for Fibre Distributed Data Interface (FDDI).

FDDI provides a high-bandwidth (100 Mbit/s), general-purpose interconnection among computers and peripheral equipment using fibre optics as the transmission medium. FDDI can be configured to support a sustained transfer rate of approximately 80 Mbit/s (10 Mbyte/s). It may not meet the response time requirements of all unbuffered high-speed devices. FDDI establishes connections among many stations distributed over distances of several kilometers in extent. Default values for FDDI were calculated on the basis of 1 000 physical links and a total fibre path length of 200 km (typically corresponding to 500 stations and 100 km of dual fibre cable).

FDDI consists of:

(a) A Physical Layer (PL), which is divided into two sublayers:

(1) A Physical Medium Dependent (PMD), which provides the digital baseband point-to-point communication between stations in the FDDI network. The PMD provides all services necessary to transport a suitably coded digital bit stream from station to station. The PMD defines and characterizes the fibre-optic drivers and receivers, medium-dependent code requirements, cables, connectors, power budgets, optical bypass provisions, and physical-hardware-related characteristics. It specifies the point of interconnectability for conforming FDDI attachments.

(2) A Physical Layer Protocol (PHY), which provides connection between the PMD and the Data Link Layer. PHY establishes clock synchronization with the upstream code-bit data stream and decodes this incoming code-bit stream into an equivalent symbol stream for use by the higher layers. PHY provides encoding and decoding between data and control indicator symbols and code bits, medium conditioning and initializing, the synchronization of incoming and outgoing code-bit clocks, and the delineation of octet boundaries as required for the transmission of information to or from higher layers. Information to be transmitted on the interface medium is encoded by the PHY into a grouped transmission code. The definition of PHY is contained in this part of ISO 9314.

(b) A Data Link Layer (DLL), which controls the accessing of the medium and the generation and verification of frame check sequences to ensure the proper delivery of valid data to the higher layers. DLL also concerns itself with the generation and recognition of device addresses and the peer-to-peer associations within the FDDI network. For the purpose of the PHY definition contained in this part of ISO 9314, references to DLL are made in terms of the Media Access Control (MAC) entity, which is the lowest sublayer of DLL.

(c) A Station Management (SMT)[1], which provides the control necessary at the station level to manage the processes under way in the various FDDI layers such that a station may work cooperatively on a ring. SMT provides services such as control of configuration management, fault isolation and recovery, and scheduling procedures.

The definition of PHY as contained in this part of ISO 9314 is designed to be as independent as possible from the actual physical medium.

ISO 9314 specifies the interfaces, functions, and operations necessary to ensure interoperability between conforming FDDI implementations. This part of ISO 9314 is a functional description. Conforming implementations may employ any design technique that does not violate interoperability.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9314. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9314 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 9314-2: 1989, *Information processing systems - Fibre Distributed Data Interface (FDDI) - Part 2: Token Ring Media Access Control (MAC).*

ISO 9314-3: ----[2], *Information processing systems - Fibre Distributed Data Interface (FDDI) - Part 3: Token Ring Physical Layer, Medium Dependent (PMD).*

3 Definitions

For the purposes of this part of ISO 9314, the following definitions apply:

3.1 code bit: The smallest signalling element used by the Physical Layer for transmission on the medium.

3.2 code group: The specific sequence of five code bits representing a DLL symbol.

3.3 concentrator: A node on the FDDI ring, which in turn provides connections for additional conforming FDDI stations so that they may communicate with other attachments to the FDDI ring. A concentrator has two Physical Layer entities and may or may not have one or more Data Link Layer entities.

3.4 Connection Management (CMT): That portion of the Station Management (SMT) function that controls network insertion, removal, and connection of PHY and MAC entities within a station.

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1) SMT will form the subject of a future part of ISO 9314.

2) To be published.

3.5 entity: An active element within an Open System Interconnection (OSI) layer, or sublayer; or SMT, in a specific station.

3.6 fibre optics: A technology whereby signals are transmitted over an optical waveguide medium through the use of light-generating transmitters and light-detecting receivers.

3.7 frame: A Protocol Data Unit transmitted between cooperating MAC entities on a ring, consisting of a variable number of octets.

3.8 nonreturn to zero (NRZ): A technique in which a polarity level high, or low, represents a logical "1" (one), or "0" (zero).

3.9 nonreturn to zero invert on ones (NRZI): A technique in which a polarity transition represents a logical "1" (one). The absence of a polarity transition denotes a logical "0" (zero).

3.10 physical connection: The full-duplex physical layer association between adjacent PHY entities (in concentrators, repeaters, or stations) in an FDDI ring, i.e., a pair of Physical Links.

3.11 physical link: The simplex path (via PMD and attached medium) from the transmit function of one PHY entity to the receive function of an adjacent PHY entity (in concentrators, repeaters, or stations) in an FDDI ring.

3.12 primitive: An element of the services provided by one entity to another.

3.13 Protocol Data Unit (PDU): Information delivered as a unit between peer entities that may contain control information, address information and data (e.g., an Service Data Unit from a higher layer).

3.14 receive: The action of a station of accepting a frame, token, or control sequence from the medium.

3.15 repeat: The act of a station in receiving a code-bit stream (e.g., frame or token) from an upstream station and placing it on the medium to the next station. The station repeating the code-bit stream examines it and may copy it into a buffer and modify control indicators as appropriate.

3.16 ring: Two or more stations in which information is passed sequentially between active stations, each station in turn examining or copying the information, finally returning it to the originating station.

3.17 Service Data Unit (SDU): The unit of data transfer between a service user and a service provider.

3.18 services: The services provided by one entity to a higher entity or to SMT.

3.19 station: An addressable logical and physical node on a ring capable of transmitting, repeating, and receiving information.

3.20 Station Management (SMT): The entity within a station on the ring that monitors station activity and exercises overall appropriate control of station activity.

3.21 symbol: The smallest signalling element used by the Data Link Layer (DLL). The symbol set consists of 16 data symbols and 8 control symbols. Each symbol corresponds to a specific sequence of code bits (code group) to be transmitted by the Physical Layer.

3.22 transmit: The action of a station that consists of generating a frame, token, or control sequence, and placing it on the medium to the next station.

4 Conventions and abbreviations

4.1 Conventions

The terms SMT, MAC, PMD and PHY, when used without modifiers, refer specifically to the local entities.

Low lines (e.g., control_action) are used as a convenience to mark the name of signals, functions, or the like, which might otherwise be misinterpreted as independent individual words if they were to appear in text.

The use of a period (e.g., PH_UNITDATA.request) is equivalent to the use of a low line except that a period is used as an aid to distinguish modifier words appended to an antecedent expression.

4.2 Abbreviations

ALS	Active_Line-state
HLS	Halt_Line-state
ILS	Idle_Line-state
MLS	Master_Line-state
NLS	Noise_Line-state
QLS	Quiet_Line-state
NRZ	Non Return to Zero
NRZI	Non Return to Zero, Invert on Ones
PI	Primary Input
PO	Primary Output
RCRCLK	Receiver Recovery Clock
SI	Secondary Input
SO	Secondary Output
Hi_Ct	Current Smoother extension (in symbols) at 14-symbol threshold
Lo_Ct	Current Smoother extension (in symbols) at 12-symbol threshold
Out_Ct	Number of symbols output in current Smoother state
T_Flag	Indicates current frame can not be stripped
D_Max	Maximum ring latency
Hi_Max	Maximum smoothing capacity (in symbols) at 14-symbol threshold
Lo_Max	Maximum smoothing capacity (in symbols) at 12-symbol threshold
P_Max	Maximum number of Physical Layer entities
SD_Max	Maximum starting delimiter delay contribution
SD_Min	Minimum starting delimiter delay

5 General description

A ring network consists of a set of stations logically connected as a serial string of stations and transmission media to form a closed loop. Information is transmitted sequentially, as a stream of suitably encoded symbols, from one active station to the next. Each station generally regenerates and repeats each symbol and serves as the means for attaching one or more devices to the network for the purpose of communicating with other devices on the network.

The basic building block of an FDDI network is a Physical Connection as shown in figure 1. A Physical Connection in the FDDI ring consists of the Physical Layers of two stations that are connected over the transmission medium by a Primary Link and a Secondary Link. A Primary link consists of an output, called Primary Out (PO), of a Physical layer, communicating over a Primary medium to the input, called Primary In (PI), of a second Physical Layer. The Secondary link consists of the output, called Secondary Out (SO), of the second Physical Layer communicating over a Secondary medium to the input, called Secondary In (SI), of the first Physical Layer. Physical Connections may be subsequently logically connected within nodes, via attached MACs or other means, to create the network.

An FDDI network consists of a theoretically unlimited number of connected stations. SMT establishes the physical connections between stations, and the correct internal station configuration, to create an FDDI network of logical rings. The method of actual physical attachment of stations to the FDDI network will vary and is dependent on specific application requirements. The function of each station is implementer defined and is determined by the specific application or site requirements.

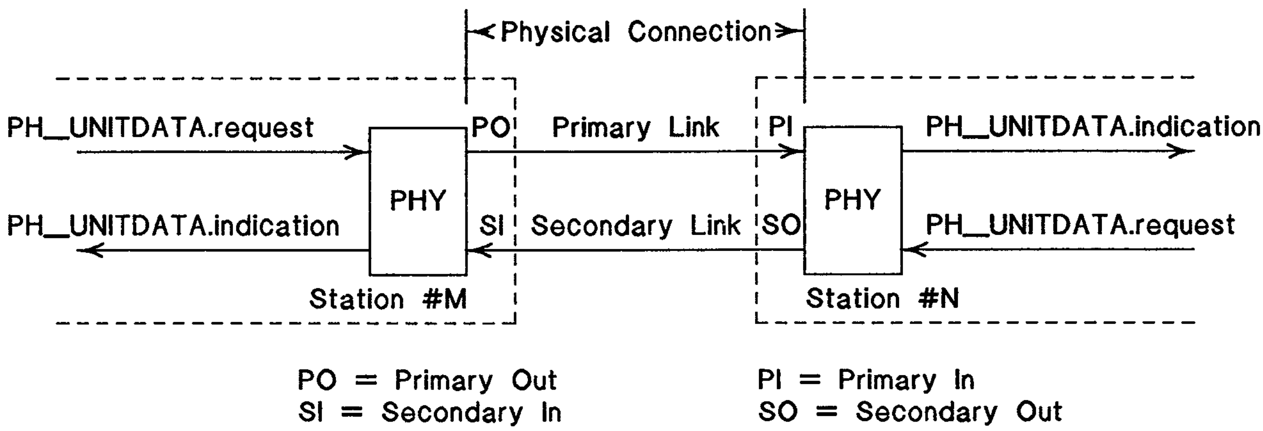

Figure 1 - FDDI physical connection example

6 Services

This clause specifies the services provided by PHY. The services as defined in this clause do not imply any particular implementation or any interface. Services described are:

(a) PHY services provided to the local MAC entity (indicated by PH_ prefix)

(b) Services required from the local PMD entity by PHY (indicated by PM_ prefix)

(c) PHY services provided to the local SMT entity (indicated by SM_PH_ prefix)

Figure 2 shows the block diagram organization of the FDDI Physical layer including the separate functions, related signals and interfaces that it contains. The interfaces and signals between the Physical Layer, the data link layer and Station Management are intended to be logical rather than physical. Any other set of signals that causes the same physical behaviour of the protocol is equally valid.

6.1 PHY-to-MAC services

This subclause specifies the services supplied by PHY to allow the local MAC entity to exchange PDUs with peer entities. Additional detail is provided in ISO 9314-2 on FDDI MAC concerning conditions that generate these primitives and MAC actions upon receipt of PHY-generated primitives. The following primitives are defined:

PH_UNITDATA.request
PH_UNITDATA.indication
PH_UNITDATA_STATUS.indication
PH_INVALID.indication

All primitives described in this clause are mandatory.

The description of each primitive includes a description of the information that shall be passed between MAC and PHY.

These services shall be "synchronous", e.g., each PH_UNITDATA.indication causes exactly one PH_UNITDATA.request. Depending upon the current internal configuration of the station, the PH_UNITDATA.request may be returned to the same PHY, or to a different PHY. Although these services are primarily intended as a PHY-to-MAC interface, they also serve as a PHY-to-PHY interface when repeating on a logical ring with no intervening MAC. In this case the function of the Repeat Filter (see 8.4) is required somewhere in the repeat path within the physical layer.

6.1.1 PH_UNITDATA.request

This primitive defines the transfer of data from MAC to PHY.

6.1.1.1 Semantics of the primitive

```
PH_UNITDATA.request          (
                             PH_Request (symbol)
                             )
```

The symbol specified by PH_Request (symbol) shall be one of the following:

J, K, T, R, S, I, n, H and optionally Q or V, where n is any of the sixteen data symbols specified in Table 1.

6.1.1.2 When generated

MAC sends PHY one PH_UNITDATA.request for each PH_UNITDATA.indication received from PHY.

6.1.1.3 Effect of receipt

Upon receipt of this primitive the PHY entity shall encode and transmit the symbol. When the PHY entity is ready to accept another PH_UNITDATA.request, it shall return to MAC a PH_UNITDATA_STATUS.indication.

NOTE - The transmission of Q, H, or V does not occur on a PH_UNITDATA.request from MAC. However, when repeating in the physical layer, a PH_UNITDATA.request of H is possible (and Q or V in implementations in which the Repeat Filter function is located after the PH_UNITDATA.request interface).

Table 1 - Symbol coding

Decimal	Code Group	Symbol	Assignment	
Line State Symbols				
00	00000	Q	QUIET	
31	11111	I	IDLE	
04	00100	H	HALT	
Starting Delimiter				
24	11000	J	1st. of Sequential SD Pair	
17	10001	K	2nd. of Sequential SD Pair	
Data Symbols				
			Hex	Binary
30	11110	0	0	0000
09	01001	1	1	0001
20	10100	2	2	0010
21	10101	3	3	0011
10	01010	4	4	0100
11	01011	5	5	0101
14	01110	6	6	0110
15	01111	7	7	0111
18	10010	8	8	1000
19	10011	9	9	1001
22	10110	A	A	1010
23	10111	B	B	1011
26	11010	C	C	1100
27	11011	D	D	1101
28	11100	E	E	1110
29	11101	F	F	1111
Ending Delimiter				
13	01101	T	Used to Terminate the Data Stream	
Control Indicators				
07	00111	R	Denoting Logical ZERO (Reset)	
25	11001	S	Denoting Logical ONE (Set)	
Invalid Code Assignments				
01	00001	V or H	These code patterns shall not be transmitted because they violate consecutive code-bit zeros or duty cycle requirements. Codes 01, 02, 08 and 16 shall however be interpreted as Halt when received.	
02	00010	V or H		
03	00011	V		
05	00101	V		
06	00110	V		
08	01000	V or H		
12	01100	V		
16	10000	V or H		

(12345) = sequential order of code-bit transmission.

6.1.2 PH_UNITDATA.indication

This primitive defines the transfer of data from PHY to MAC.

6.1.2.1 Semantics of the primitive

```
PH_UNITDATA.indication          (
                                PH_Indication (symbol)
                                )
```

The symbol specified by PH_Indication (symbol) shall be one of the following: J, K, T, R, S, I, n, H and optionally Q or V, where n is any of the sixteen data symbols specified in Table 1. The indication of Q or V is not required in implementations where the Repeat Filter function is located prior to the PH_UNITDATA.indication interface.

6.1.2.2 When generated

PHY shall send MAC a PH_UNITDATA.indication every time it decodes a symbol received from PMD. This indication is sent once every symbol period.

6.1.2.3 Effect of receipt

Upon the receipt of this primitive, MAC accepts a symbol from PHY, processes it, and generates a corresponding PH_UNITDATA.request to PHY; also conveying the resulting output symbol.

6.1.3 PH_UNITDATA_STATUS.indication[1)]

This primitive has local significance and shall provide an appropriate response to the PH_UNITDATA.request primitive signifying the acceptance of a symbol specified by the PH_UNITDATA.request and willingness to accept another symbol.

6.1.3.1 Semantics of the primitive

```
PH_UNITDATA_STATUS.indication   (
                                transmission_status
                                )
```

The transmission_status parameter shall be used to signify the transmission completion status.

6.1.3.2 When generated

PHY shall send MAC PH_UNITDATA_STATUS.indication in response to every PH_UNITDATA.request received. The purpose of the PH_UNITDATA_STATUS.indication is to synchronize the MAC data output with the data rate of the medium.

6.1.3.3 Effect of receipt

The effect of receipt of this primitive by MAC is not specified.

---

1) This primitive is not used by ISO 9314-2 on FDDI MAC.

6.1.4 PH_INVALID.indication

This primitive is generated by PHY and asserted to MAC to indicate that the symbol stream has been detected as invalid.

6.1.4.1 Semantics of the primitive

```
PH_INVALID.indication          (
                               PH_Invalid
                               )
```

The PH_Invalid parameter shall indicate that the symbol stream is invalid.

6.1.4.2 When generated

PHY shall generate this primitive whenever it detects a Quiet, Halt, Master, or Noise_Line-State. In addition, PHY shall generate this primitive for input error conditions detected by PHY (such as Elasticity Buffer errors) if the implementation does not report them as Violation symbols in the PH_UNITDATA.indication symbol stream.

6.1.4.3 Effect of receipt

The effect of receipt of this primitive by MAC is not specified.

6.2 PHY-to-PMD services

This subclause specifies the services provided at the interface between the PHY and the PMD entities of the Physical layer, to allow PHY to exchange an NRZI code-bit stream with peer PHY entities. Additional detail is provided in PMD concerning conditions that generate these primitives and PMD actions upon receipt of PHY-generated primitives.

The following primitives are defined:

- PM_UNITDATA.request
- PM_UNITDATA.indication
- PM_SIGNAL.indication

The description of each primitive includes a description of the information that is passed between the PHY and PMD entities.

The implementation of the PHY to PMD interface is not specified. However, an exemplary implementation of this interface is provided as an annex to ISO 9314-3.

6.2.1 PM_UNITDATA.request

This primitive defines the transfer of NRZI data from PHY to PMD.

6.2.1.1 Semantics of the primitive

```
PM_UNITDATA.request            (
                               PM_Request (NRZI code)
                               )
```

The data conveyed by PM_Request shall be a continuous NRZI code (i.e., each polarity change in PM_Request signifies a NRZI code "one").

6.2.1.2 When generated

PHY continuously sends PMD the current NRZI code polarity.

6.2.1.3 Effect of receipt

The effect of receipt of this primitive by PMD is not specified.

6.2.2 PM_UNITDATA.indication

This primitive defines the transfer of NRZI data from PMD to PHY.

6.2.2.1 Semantics of the primitive

```
PM_UNITDATA.indication          (
                                PM_Indication (NRZI code)
                                )
```

The data conveyed by PM_Indication shall be a continuous NRZI code (i.e., each polarity change in PM_Indication signifies a NRZI code "one").

6.2.2.2 When generated

PMD continuously sends PHY the current NRZI code polarity.

6.2.2.3 Effect of receipt

In normal non-Loopback mode, PM_Indication is continuously sampled by the clock recovery and Receive Function of PHY.

6.2.3 PM_SIGNAL.indication

This primitive is generated by PMD and asserted to PHY to indicate a change in the status of the optical signal level being received by PMD.

6.2.3.1 Semantics of the primitive

```
PM_SIGNAL.indication            (
                                Signal_Detect(status)
                                )
```

The Signal_Detect(status) parameter shall indicate whether the inbound optical signal level is above (status = on) or below (status = off) the optical signal detection threshold of the optical receiver in PMD.

6.2.3.2 When generated

PMD generates this primitive whenever it detects a change in the status of Signal_Detect.

6.2.3.3 Effect of receipt

The effect of receipt of this primitive is, when status = off, to enter Quiet_Line-State, and when status = on, to enable detection of other line states.

6.3 PHY-to-SMT services

The services supplied by the PHY allow the local SMT entity to control the operation of PHY. The PHY shall perform the requested SMT services preemptively over any requested MAC services. Additional detail is provided in SMT concerning conditions that generate these primitives and SMT actions upon receipt of PHY-generated primitives. The following primitives are defined:

SM_PH_LINE-STATE.request
SM_PH_STATUS.indication
SM_PH_CONTROL.request

All primitives described in this subclause are mandatory. The description of each primitive includes a description of the information that is passed between PHY and SMT.

6.3.1 SM_PH_LINE-STATE.request

This primitive is generated by SMT to request PHY to send a stream of symbols.

6.3.1.1 Semantics of the primitive

```
SM_PH_Line-State.request          (
                                  Line-State_action
                                  )
```

The line-state_action parameter shall be one of the following:

TRANSMIT_QUIET. When this action is requested, PHY shall send a continuous stream of Quiet symbols to PMD. In this condition the Transmit Function generates no transitions. TRANSMIT_QUIET shall also be the default condition of the PHY Transmit Function initially, or after a PHY_Reset.

NOTE – To ensure the proper effect on the optical signal, SMT should also issue an appropriate SM_PM_CONTROL.request to PMD.

TRANSMIT_HALT. When this action is requested, PHY shall send a continuous stream of Halt symbols to PMD.

TRANSMIT_IDLE. When this action is requested, PHY shall send a continuous stream of Idle symbols to PMD.

TRANSMIT_MASTER. When this action is requested, PHY shall send a continuous stream of alternating Halt and Quiet symbol pairs to PMD.

TRANSMIT_PDR. When this action is requested, PHY shall send the stream of symbols presented to the PH_UNITDATA.request interface by MAC to PMD.

NOTE – The symbol stream may be modified if the Repeat Filter function is located downstream from the PH_UNITDATA.request interface.

6.3.1.2 When Generated

These primitives are generated by SMT as part of station insertion or removal sequences.

6.3.1.3 Effect of receipt

PHY shall send a continuous stream of the commanded symbol(s) to PMD. These primitives shall take precedence over the MAC-to-PHY primitives.

6.3.2 SM_PH_STATUS.indication

This primitive is generated by PHY to inform SMT of line state activity and status changes. The specific items reported are defined in the following subclause.

6.3.2.1 Semantics of the primitive

```
SM_PH_STATUS.indication          (
                                 status_report
                                 )
```

The status_report parameter shall be one of the following (see 7.3 for description of line states):

QUIET_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Quiet_Line-State (QLS) is entered.

HALT_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Halt_Line-State (HLS) is entered.

MASTER_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Master_Line-State (MLS) is entered.

IDLE_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Idle_Line-State (ILS) is entered.

ACTIVE_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Active_Line-State (ALS) is entered.

NOISE_LINE-STATE_RECEIVED. This parameter shall be asserted by PHY when the Noise_Line-State (NLS) is entered.

LINE-STATE_UNKNOWN. This parameter shall be asserted by PHY when any of the defined line states are exited and the entry conditions to a new line state have not yet been satisfied. Also included shall be an indication of the most recently known line state.

6.3.2.2 When Generated

These primitives shall be generated by PHY to signal the occurrence of the indicated condition.

6.3.2.3 Effect of receipt

The effect of receipt of this primitive by SMT is not specified.

6.3.3 SM_PH_CONTROL.request

This primitive has local significance and is used by SMT to control the operation of PHY.

6.3.3.1 Semantics of the primitive

SM_PH_CONTROL.request (
Control_Action,
Requested_Status
)

The Control_Action parameter shall include the following: Reset, Present_Status, Begin_Loopback, or Cancel_Loopback.

The Requested_Status parameter shall include the current line state. If the current line state is unknown, then LINE-STATE_UNKNOWN shall be reported along with the most recent known line state.

6.3.3.2 When generated

This primitive is generated by SMT to cause PHY to take the action specified by the Control_Action parameter.

6.3.3.3 Effect of receipt

The status of the control_action parameter shall determine the effect upon PHY as follows:

(a) If the Control_Action is Reset, then PHY shall at a minimum:

(1) Reset the transmit mode to TRANSMIT_QUIET.

(2) Reset the Elasticity Buffer function.

(3) Reset the line state to LINE-STATE_UNKNOWN.

(4) Reset the line state counters.

(5) Reset the Smoothing function.

(6) Reset the Repeat Filter function.

(b) If the Control_Action is Present_Status, then PHY shall present the status to SMT as indicated by the Requested_Status parameter.

(c) If the Control_Action is Request_Loopback, then PHY shall enter the Loopback mode. The intent of this mode is to loop back within the PHY entity at a point as close as possible to the interface with PMD to permit local station testing. In this mode, PHY shall return symbols presented at the PH_UNITDATA.request interface on the PH_UNITDATA.indication interface. These symbols may be altered by the action of the Repeat Filter (see 8.4 for description of Repeat Filter). PHY shall present continuous NRZI code-bit zeros to the PM_UNITDATA.request interface while in Loopback mode. It is required that the NRZI code used be that which results in no light output.

(d) If the Control_Action is Cancel_Loopback, then PHY shall leave Loopback mode.

7 Facilities

7.1 Coding

7.1.1 Code bit

Peer Physical Layer entities on the ring communicate via fixed-length code bits. A code bit is the smallest primitive signalling entity used by the Physical Layer wherein a code bit is represented as a transition, or absence of a transition, on the medium.

7.1.2 Code group

A code group is a consecutive sequence of five code bits and is used to represent a symbol on the medium. Implicit in the definition of code group is an establishment of code-group boundaries by the Physical Layer.

7.2 Symbol set

Peer DLL entities on the ring communicate via a set of fixed-length symbols. These symbols are passed across the MAC-to-PHY interface via the PH_UNITDATA.request and PH_UNITDATA.indication primitives.

7.2.1 Line state symbols

These three symbols are reserved for use on the medium between transmissions. Detection of any of these symbols within a frame shall preempt and abnormally terminate any data transmission sequence in process.

7.2.1.1 Quiet (Q)

The Quiet symbol indicates the absence of any transitions on the medium.

7.2.1.2 Halt (H)

The Halt symbol indicates control sequences (in the form of line states) or the removal of code violation symbols from the symbol path while minimizing any dc component of the ac signal being placed on the transmission medium.

7.2.1.3 Idle (I)

The Idle symbol indicates the normal condition of the medium between transmissions. It provides a continuous fill pattern to establish and maintain clock synchronism.

7.2.2 Control symbols

7.2.2.1 Starting Delimiter (SD)

A Starting Delimiter (SD) is used to delineate the starting boundary of a data transmission sequence. This data transmission may begin when the medium is in the idle condition or it may succeed or preempt a previous transmission. The SD is unique in that it may be recognized independent of previously established symbol boundaries. Note that the Starting Delimiter may occur at any point regardless of previously established code-group boundaries, such as in the case in which a new transmission preempts a previous transmission, thereby abnormally terminating it.

The DLL is responsible for maintaining proper Starting Delimiter usage and code-group sequencing. A sequential symbol sequence of J and then K, from the DLL to PHY, shall be used to impress the Starting Delimiter on to the transmission medium. As described in clause 5, the Physical Layer shall represent the JK sequence as a uniquely recognizable code-bit sequence that does not exist in any other legal symbol sequence regardless of previously established symbol boundaries. Using this characteristic, the receiving logic of the Physical Layer uses the incoming JK sequence to establish code-group boundaries.

7.2.2.1.1 Initial SD symbol (J)

The J symbol is the first symbol of a sequential Starting Delimiter symbol pair.

7.2.2.1.2 Final SD symbol (K)

The K symbol is the second and last symbol of a sequential Starting Delimiter symbol pair.

7.2.2.2 Ending Delimiter (ED)

An Ending Delimiter (T) terminates all normal data transmissions. The T symbol is not necessarily the last symbol in a transmission sequence, since the Ending Delimiter may be followed by one or more Control Indicator symbols. However, Ending Delimiters and Control Indicators shall always form a sequence of balanced, i.e., even number of symbol pairs. When no Control Indicators are present, this sequence consists of a pair of T symbols. Note that the Ending Delimiter can not be recognized independent of symbol boundaries so that proper decoding of this code group depends on the previous establishment of code-group clocking boundaries.

7.2.2.3 Control indicators

Control indicators specify logical conditions associated with a data transmission sequence. They may be independently altered by repeating stations without altering the normal data in the transmission sequence. A sequence of Ending Delimiter and control indicators symbols is always balanced, i.e., it consists of even pairs of symbols. An Ending Delimiter followed by an odd number of Control Indicators is a balanced symbol sequence; however, an Ending Delimiter followed by an even number of control indicators is balanced by adding a final Ending Delimiter. The DLL is responsible for maintaining Control Indicator Balance. Note that the proper decode of these control indicators depends on the previously established code-group clocking boundaries, and thus is transparent to the Physical Layer.

7.2.2.3.1 Reset (R)

The Reset symbol indicates a logical zero (reset) condition.

7.2.2.3.2 Set (S)

The Set symbol indicates a logical one (set) condition.

7.2.3 Data symbols (0-F)

A Data Symbol conveys one quartet of arbitrary data within a transmission sequence. The elements of the sixteen Data Symbols are denoted by the hexadecimal digits (0-F) and a nonspecific member of the set is denoted by the character *n*.

The use of Data symbols is arbitrary, where any Data symbol can be followed by any other Data symbol. Data symbols are not interpreted by PHY. Successful decoding of these code-groups by PHY depends on proper receipt of the Starting Delimiter sequence as previously defined.

7.2.4 Violation symbol (V)

The Violation symbol denotes a condition on the medium that does not conform to any other symbol in the symbol set. Violation symbols shall not be transmitted on to the medium. The receipt of Violation symbols may result from various error conditions or during ring clock synchronization sequences.

7.3 Line states

This clause defines the line states that determine and control the status of a Physical Link. These line states are generated by PHY upon request from SMT (via SM_PH_CONTROL.request), and are detected by PHY and reported to SMT (via SM_PH_STATUS.indication). The line states represent a longer term condition of the Physical Link than that represented by a symbol or a symbol pair. Line state detection is provided at all times but accuracy need not be guaranteed during the clock acquisition interval or during line state drop out intervals (see 8.2.3). Note that the following line state definitions are mutually exclusive, but not exhaustive, i.e., line conditions exist that do not satisfy the criteria for any of the defined line states. In this case, the current line state is unknown, which is the default condition.

PHY shall report any change in the received line state to SMT via the SM_PH_STATUS.indication primitive.

PHY shall report a PH_INVALID.indication to MAC whenever the received line state is QLS, MLS, HLS, or NLS.

At any time, SMT shall be able to determine the current line state via the SM_PH_CONTROL.request primitive. If the current line state is unknown, then Line-State_Unknown shall be reported to SMT along with the most recently known line state.

7.3.1 Quiet_Line-State (QLS)

A continuous stream of Quiet symbols shall be sent by PHY to signal the Quiet_Line-State. This line state is used as part of the Physical Connection establishment process. It may also indicate the absence of a physical connection.

Quiet_Line-State shall be entered upon loss of Signal_Detect(on) from PMD, or upon the receipt of sixteen or seventeen consecutive Q symbols with Signal_Detect(on).

Quiet_Line-State shall be exited upon receipt of any symbol other than Q with Signal_Detect(on).

7.3.2 Master_Line-State (MLS)

A continuous stream of alternating Halt and Quiet symbols shall be sent by PHY to signal the Master_Line-State. This line state is used as part of the Physical Connection establishment process.

Master_Line-State shall be entered upon the receipt of eight or nine consecutive HQ (or QH) symbol pairs with Signal_Detect(on).

Master_Line-State shall be exited upon receipt of any symbol pair other than HQ (or QH), or loss of Signal_Detect(on).

7.3.3 Halt_Line-State (HLS)

A continuous stream of Halt symbols shall be sent by PHY to signal the Halt_Line-State. This line state is used as part of the Physical Connection establishment process.

Halt_Line-State shall be entered upon the receipt of sixteen or seventeen consecutive H symbols with Signal_Detect(on).

Halt_Line-State shall be exited upon receipt of any symbol other than H, or loss of Signal_Detect(on).

7.3.4 Idle_Line-State (ILS)

A continuous stream of Idle symbols shall be sent by PHY to signal the Idle_Line-State. This line state is used to establish and maintain clock synchronization on the outbound Physical Link. This line state is used both as part of the Physical Connection establishment process and between MAC frame sequences during normal operation.

Idle_Line-State shall be entered upon the receipt of four or five consecutive I symbols with Signal_Detect(on) (and Clock_Detect asserted, if implemented). Note that this may be increased by up to eleven bits if the Elasticity Buffer Function is implemented before the Line State Detection Function, and it removes the maximum number of bits permitted (i.e., twenty bits maximum to nine bits minimum equals eleven bits).

Idle_Line-State shall be exited upon receipt of any symbol other than I, or loss of Signal_Detect(on) (or Clock_Detect deasserted, if implemented).

7.3.5 Active_Line-State (ALS)

When PHY transmits a MAC frame sequence on the outbound Physical Link, this signals that the associated Physical Connection is enabled in this station (i.e., whenever a MAC frame sequence is sent or repeated by this station with the TRANSMIT_PDR (see 6.3.1) mode enabled). When detected, Active_Line-State indicates that the inbound symbol stream on the Physical Link is a MAC frame sequence, and that the neighbouring PHY has enabled the associated physical connection.

Active_Line-State shall be entered upon the receipt of a JK symbol pair on any arbitrary code-bit boundary in the input NRZ stream, with Signal_Detect(on) (and Clock_Detect asserted, if implemented).

Active_Line-State shall be exited upon receipt of any symbol other than I, n, R, S, or T, or loss of Signal_Detect(on) (or Clock_Detect deasserted, if implemented), or entry into the Idle_Line-State. A JK received while in ALS (on any arbitrary bit boundary) may cause an exit from ALS (and a subsequent re-entry to ALS) but this is not required.

7.3.6 Noise_Line-State (NLS)

PHY shall not transmit a symbol stream that can cause Noise_Line-State to be detected by the neighbouring PHY. When detected, Noise_Line-State indicates that the inbound Physical Link is noisy and that, if NLS persists, the associated Physical Connection is faulty.

Noise_Line-State shall be entered upon the occurrence of sixteen or seventeen potential noise events without satisfying the criteria for entry to another line state. Potential noise events shall include decoding a Q, H, J, K, or V symbol (or a symbol pair containing at least one Q, H, J, K, or V symbol) with Signal_Detect(on). An implementation may also optionally count as potential noise events:

(a) An Elasticity Buffer error with Signal_Detect(on).

(b) Decoding a mixed (control and data) symbol pair with Signal_Detect(on).

(c) Decoding an n, R, S, or T symbol (or a symbol pair containing at least one n, R, S, or T symbol) with Signal_Detect(on) (and Clock_Detect asserted, if implemented) when the current (or last known) line state is not ILS or ALS.

(d) If Clock_Detect is implemented, decoding an I, n, R, S, or T (or a symbol pair containing JK or at least one I, n, R, S, or T) with Signal_Detect(on) but Clock_Detect not asserted.

For a description of Signal_Detect and Clock_Detect, see 6.2.3 and 8.2.3, respectively.

The count of potential noise events shall be reset to zero whenever the criteria for entering or continuing another line state are satisfied.

Noise_Line-State shall be exited upon satisfying the criteria for entry to another line state. If the criteria for NLS and another line state occur simultaneously, the other line state shall take precedence.

8 Operation

8.1 Coding overview

Successful operation of a serial baseband transmission system, such as FDDI, requires the use of coding to combine the functions of data and clock transmission. Data recovery of this serial code-bit stream requires the recovery of synchronizing clock information which is inherent in the code-bit stream. All information is conveyed on the interface by positioning transitions, or lack of transitions, on the interface medium. The minimum time interval between possible transitions on the interface medium is defined as the "code-bit cell." Ideally, each transition, or lack of a transition represents a useful piece of data. However, in practice, this is not feasible because an extended series of bits represented by no transition would not contain sufficient information to recover the synchronizing clock. Furthermore, for high-speed serial transmission, it is desirable that dc balance be maintained to the degree feasible in order to facilitate interface component and circuit designs.

The FDDI Physical Layer employs a dual embedded coding structure so as to achieve these characteristics. The resultant serial code-bit stream, as seen on the transmission medium, contains at least two transitions for each transmitted symbol and is thus self clocking, has a maximum of three consecutive code-cell zeros and is thus run-bounded, and yields a ±10% maximum cumulative dc component variation from nominal center.

The first level of coding performed by PHY is the conversion of symbols, from MAC, to encoded NRZ code bits. The second level of coding performed by PHY consists of NRZ code-bit translation to NRZI code bits. For the incoming pulse stream, NRZI code bits shall be first decoded to NRZ code-bits and then decoded to hexadecimal symbols for use by MAC.

All information on the FDDI is sent as a sequence of code-groups, each containing a specific sequence of five code bits. The transmitted sequence of these code groups is determined by MAC. The interface between MAC and PHY uses symbols to convey logical meaning. MAC ensures that the sequence of symbols, sent to PHY for coding and transmission onto the medium, is valid and in conformance with the rules of symbol sequencing as further defined in this part of ISO 9314.

8.1.1 Symbol sequencing

MAC conveys information to PHY by a continuous stream, or sequence, of symbols. A symbol is the smallest primitive signalling entity used by MAC.

Symbols are used to convey three types of information:

(a) Line States, such as the Quiet_Line-State or Halt_Line-State.

(b) Control symbols used with Starting Delimiter, Ending Delimiter, or Control Indicator sequences.

(c) Data symbols, which are the smallest primitive data grouping used by MAC, in which four data bits comprise a "data quartet".

8.1.2 Symbol/NRZI coding

Each symbol signalled between MAC and PHY describes a specific sequence of five code bits, called a code group, to be transmitted.

The FDDI shall use an embedded group transmission code in which a fixed sequence, or group, of four data bits, or a control symbol, is coded into a fixed sequence, or group, of five code bits. The group of N code bits is called a "code group." The symbol clock frequency is one-fifth the base frequency as defined in 8.2.7. PHY accepts, or presents, a symbol from, or to, MAC once every symbol time. A symbol time is five times the code-bit cell time. Each symbol, whether a data quartet, line state, or a control symbol, is encoded by PHY into a group of five NRZ code bits, which are in turn encoded into a sequence of five NRZI code bits for transmission across the medium.

The precise assignment of five code-bit sequences to symbols is defined in table 1. The rules for usage of these symbols, and the meanings assigned to these symbols, are defined in clause 7.

Table 1 defines invalid code groups that shall not be transmitted on to the medium because they cause an unacceptable dc component in the ac signal or they cause an unacceptable number of consecutive zeros on the transmission medium. PHY shall indicate to MAC the receipt of an invalid code group as a Violation (V) symbol.

8.2 General organization

The functional organization of the FDDI PHY is shown in figure 2. The functional organization described in this subclause is of an exemplary nature.

8.2.1 Encode Function

The Encode Function of PHY is responsible for encoding symbols, as commanded by SMT or the PH_UNITDATA.request, into NRZ code bits. Each symbol is encoded into a unique five-bit code group for delivery to the Transmit Function. The code group is presented serially to the

Transmit Function as a continuous serial stream of NRZ code bits. A local fixed frequency oscillator is used to clock the symbols from MAC and the code bits to the Transmit Function.

The Encode Function of PHY is set in different transmit modes by SMT via the SM_PH_LINE-STATE.request.

When the Encode Function is set in any transmit mode other than TRANSMIT_PDR, the Encode Function shall ignore the PH_UNITDATA.request and continuously encode the symbols commanded by the transmit mode.

8.2.2 Transmit Function

The Transmit Function shall encode the NRZ code-bit serial stream from the Encode Function into an equivalent NRZI pulse stream for presentation to PMD. An annex to ISO 9314-3 on FDDI PMD provides an exemplary interface specification.

8.2.3 Receive Function

The Receive Function is responsible for decoding the electrical NRZI pulse stream from PMD into an equivalent NRZ pulse stream for presentation to other functions within PHY. An annex to ISO 9314-3 on FDDI PMD provides an exemplary interface specification.

This function shall also derive a clock, at the code-bit frequency (125 MHz), from the incoming pulse stream. A phase-locked loop may be used for this purpose. This clock, called the Receiver Recovery Clock (RCRCLK), is used to synchronize the incoming code-bit cell boundaries during the Idle and Active_Line-States, and may also be used to synchronize detection of the Halt and Master_Line-States. Alternatively, some other synchronization technique may be used to detect the Halt and Master_Line-States. The RCRCLK recovery function may also provide an optional Clock_Detect signal that, when asserted, indicates that RCRCLK is successfully locked in frequency and phase to the incoming NRZI code-bit stream. When implemented, the Clock_Detect signal is used by the Line State Detection function. RCRCLK acquisition time is constrained by the line state detection times specified in 8.2.6.

8.2.4 Elasticity Buffer Function

The Receiver Recovery Clock (RCRCLK) is used to recover the timing information from the incoming serial bit stream. It is locked in frequency and phase to the local fixed frequency oscillator of the Transmit Function of the previous upstream station. The output serial bit stream is clocked by the local fixed frequency oscillator. The frequency difference between the incoming bit frequency and the outgoing bit frequency is, at most, equal to 0,01% of the nominal frequency. The incoming frequency can be either slower or faster than the outgoing frequency, resulting in an excess or a deficiency of bits unless some compensation is included.

An elasticity buffer is used in each station to compensate for the difference in frequencies. To allow for bits that are to be dropped when the outgoing frequency is less than the incoming frequency, the MAC entity, which originates a frame, inserts at least sixteen IDLE symbols before each frame to be transmitted. The operation of the elasticity buffer in subsequent repeating stations may change the length of the IDLE pattern as described herein. An elasticity buffer is similar in function to a first-in first-out memory, which is filled halfway before bits are removed. The input clock to the Elasticity Buffer function is RCRCLK. The output clock to the elasticity buffer function is the local fixed frequency oscillator clock (LOCAL CLOCK).

The minimum required elasticity shall be ±4,5 code bits. The required elasticity is calculated as follows: 9 000 symbols equals 45 000 code bits. With a clock tolerance of 0,005% the maximum frequency variance between RCRCLK and LOCAL CLOCK is 0,01%. Calculating 0,01% of 45 000 code bits yields 4,5 code bits.

Although Figure 2 shows the Elasticity Buffer function preceding the Decode function, any implementation that meets the following rules is permitted:

(a) When entering Active_Line-State from Idle_Line-State and both the RCRCLK and the LOCAL CLOCK are within tolerance, the initial JK symbol pair and the subsequent contiguous PH_UNITDATA.indication symbol stream shall be reproduced from the input NRZ bit stream using the symbol framing reference provided by the JK code-bit pattern, without inserting, deleting, or modifying any symbols until one of the following occurs:

(1) At least 9 000 PH_UNITDATA.indication symbols have been presented since the last entry to Active_Line-State (see rule (b))

(2) From nine to twenty (depending on implementation) consecutive code-bit ones have been received in the input NRZ bit stream, independent of the symbol framing reference (see rules (c) and (d))

(3) Zero to nine code bits (depending on the difference between the new and previous framing boundaries) prior to encountering the start of another JK code-bit pattern on any arbitrary boundary in the input NRZ bit stream (see rule (e))

(4) A PH_UNITDATA.indication symbol is presented that causes an exit from Active_Line-State (see rule (f))

NOTE – If the Repeat Filter or Smoother functions are implemented prior to the PH_UNITDATA.indication, their operation may also modify the PH_UNITDATA.indication from that represented by the input NRZ stream.

(b) When in Active_Line-State and error conditions exist in the local or upstream station (i.e., if either the RCRCLK or the LOCAL CLOCK are out of tolerance, or after 9 000 consecutive PH_UNITDATA.indication symbols have been presented without reaching condition (a)(2)), an Elasticity Buffer error may occur, after which PH_UNITDATA.indication symbols may be inserted, deleted, or modified from the input NRZ bit stream. All Elasticity Buffer errors while in Active_Line-State shall be reported to SMT as well as being reported to MAC as one of the following:

(1) A PH_UNITDATA.indication with a violation (V) symbol parameter

(2) A PH_INVALID.indication

A violation symbol is preferred to a PH_INVALID.indication to allow the TVX timer in MAC to remain enabled. Also, by using a violation symbol, the PH_UNITDATA.indication symbol stream can be used directly as a PH_UNITDATA.request symbol stream when repeating in certain station configurations (e.g., on the secondary logical ring without a second MAC in the station); whereas additional logic would otherwise be needed to combine the PH_INVALID.indication and the PH_UNITDATA.indication to ensure a violation symbol is presented on the corresponding PH_UNITDATA.request.

(c) After the receipt of nine consecutive code-bit ones in the input NRZ bit stream, an implementation may insert or delete code-bit ones in the received NRZ bit stream without causing an Elasticity Buffer error, provided that the resulting bit stream contains at least nine code-bit ones. This guarantees at least one Idle symbol in the resulting symbol stream independent of symbol boundary.

(d) After the receipt of twenty consecutive code-bit ones in the input NRZ bit stream, an implementation shall be capable of Idle bit insertion/deletion without Elasticity Buffer errors as long as code-bit ones continue to be received. The resulting bit stream shall contain at least nine code-bit ones.

(e) While in Active_Line-State, if another JK code-bit pattern on any arbitrary boundary is received in the input NRZ bit stream, up to four code bits may be inserted or deleted (nine code bits for a byte-wide implementation) prior to the PH_UNITDATA.indication (JK) symbol pair. It is not required that Active_Line-State be exited, therefore the requirement of at least 9 000 PH_UNITDATA.indication occurrences before an elasticity buffer error is allowed is calculated from the original entry to Active_Line-State.

If additional symbols are inserted, the extra bits for these symbols shall either be code-bit ones or shall represent a duplication of the received code-bit stream possibly including from one to nine leading bits of the JK symbol pair. If an implementation is capable of duplicating more than four leading bits of a JK symbol pair (and thus duplicating the J), then either the Decode function or the Repeat Filter function of that implementation shall interpret a J not followed by a K as either Idle or a code violation.

Deleted data shall only be those code bits between the new and previous framing boundaries except as otherwise permitted by rule (a).

(f) When not in the Active_ or Idle_Line-States, the PH_UNITDATA.indication symbol stream can be altered from the input NRZ bit stream; however, upon exit from Active_Line-State, at least the first four consecutive invalid symbols (i.e., neither Idle symbols nor JK symbol pairs) shall be propagated as invalid symbols. Subsequently, Idle symbols may be generated, but spurious JK symbol pairs shall not be generated. Elasticity Buffer errors may occur, but only need to be recognized to the extent that they contribute to Noise_Line-State detection.

8.2.5 Decode Function

The Decode function accepts the serial NRZ code-bit stream, synchronized to LOCAL CLOCK, from the Elasticity Buffer function. The decode function shall establish symbol boundaries (or byte boundaries for byte-wide implementations), maintain synchronization to the symbol clock as appropriate to the implementation, and decode the incoming NRZ pulse stream into a continuous stream of symbols for presentation to MAC.

Although not specifically required, it is envisioned that most MAC implementations will require a clock signal from PHY once every symbol (or byte) time for the purposes of strobing symbols to or from PHY and for running the MAC logic. Proper operation of MAC may require that this clock be continuous and uninterrupted. Note that reestablishment of new code-group boundaries may be necessary owing to the recognition of a new JK Starting Delimiter sequence. In practice, the decode function of PHY has the ability to insert a 0, 1, 2, 3, or 4 code-bit delay (or a 0 to 9 code-bit delay for byte-wide implementations) into the serial pulse stream so as to allow the clock to maintain a constant phase.

If the Decode function adds or deletes code bits from the code-bit stream when reestablishing code-group boundaries, then the combined effect of the Elasticity Buffer function and the Decode function shall follow the rules for the Elasticity Buffer function in 8.2.4.

8.2.6 Line State Detection Function

The Line State Detection function is used to determine the line state of the inbound Physical Link. The line states represent a longer term condition of the Physical than that represented by a symbol or a symbol pair (see 7.3 for the definitions of the line states). The Line State

Detection function also uses the PM_SIGNAL.indication, as well as the optional signals from the Receive Function (Clock_Detect) and the Elasticity Buffer errors, to determine the current line state. This function signals the local MAC entity (via PH_INVALID.indication) when the symbol stream has been detected as invalid and the local SMT entity (via SM_PH_STATUS.indication) of any changes to the detected line state.

The initial line state detection interval begins when both a Signal_Detect(on) and a PM_Indication(NRZI code) serial data stream meeting the criteria for entering or maintaining the Halt, Master, Idle, or Active_Line-State are received from PMD, and continues until the line state reported to SMT correctly indicates the state of the serial data stream being received from PMD. This interval shall not exceed the Maximum PHY Acquisition Time (AT_Max). The default value of AT_Max is 100 µs. During this interval Line-State_Unknown or Noise_Line-State shall be reported to SMT (see 7.3). The Maximum Signal Acquisition Time (A_Max) used by the MAC and SMT entities is the sum of AT_Max plus the Maximum PMD Acquisition Time (AS_Max).

After initial line state detection, the correct line state may change or be temporarily lost. Loss of the correct line state results from internal conditions within the receiving PHY entity (e.g., loss of RCRCLK synchronization or Elasticity Buffer errors), whereas changes in line state result from changes outside the receiving PHY entity (e.g., change in transmitted line state or in the state of PMD). After initial line state detection, upon any subsequent change or loss of the line state being received from PMD, the time to reestablish the correct line state shall not exceed the Maximum Line State Change Time (LS_Max). The default value of LS_Max is 15 µs. During this time, Line-State_Unknown or Noise_Line-State shall be reported to SMT (see 7.3).

Note that the detection of the Idle and Active_Line-States (and optionally the Halt and Master_Line-States) requires RCRCLK synchronization. Consequently, RCRCLK acquisition time in an implementation is constrained by the AT_Max or the LS_Max criteria, or by both. If an implementation requires RCRCLK to detect Halt or Master_Line-State, then RCRCLK acquisition time on these patterns (HLS or MLS) must be less than AT_Max. Otherwise, a subsequent switch from Halt or Master_Line-State to Idle or Active_Line-State requires RCRCLK acquisition on these patterns (ILS or ALS) in less than LS_Max.

8.2.7 Local Clock

A Local Clock is used for the purposes of establishing the base frequency used by the various functions in PHY. This clock shall be derived from a fixed frequency oscillator, which is created locally within PHY implementation or externally within the Station. Characteristics of the Local Clock shall be:

(a) Fixed frequency oscillator base frequency = 125 MHz ±0,005% (50 ppm)

(b) Phase jitter (above 20 kHz) < ±8° (±0,14 rad)

(c) Harmonic content (above 125,02 MHz) < -20 dB

(d) Nominal code-bit cell time = 8,0 ns

(e) Nominal symbol time = 40,0 ns

8.3 Smoothing Function

Each PHY shall process the symbol stream using a Smoothing function. This function compensates for the possibility that multiple PHY Elasticity Buffer functions delete symbols from the same preamble. Unconstrained preamble shrinkage can result in loss of frames. The FDDI design constraints include:

(a) The Elasticity Buffer is not required to recenter on preambles shorter than four symbols

(b) MAC is not required to repeat frames with preambles shorter than two symbols

(c) MAC is not required to copy frames with preambles shorter than twelve symbols

The Smoothing function absorbs surplus symbols from longer preambles and redistributes them into shorter preambles. This significantly reduces the variance of preamble sizes during long bursts of frames.

The Smoothing function shall be capable of inserting additional preamble symbols into repeated preambles shorter than fourteen symbols. This smoothing capability shall be reclaimed by deleting excess symbols from preambles longer than fourteen symbols. The smoothing capacity at the fourteen-symbol threshold, called Hi_Max, shall be at least two symbols.

In stations whose MACs require eleven or twelve preamble symbols to copy frames properly, the Smoothing function shall also be capable of inserting additional preamble symbols into preambles shorter than twelve symbols. This smoothing capability shall be reclaimed by deleting excess symbols from preambles longer than twelve symbols. The additional smoothing capacity (beyond Hi_Max) at the twelve-symbol threshold, called Lo_Max, shall be at least two symbols for such stations, or zero symbols otherwise.

The total smoothing capacity of a station at these thresholds is defined as Hi_Max plus Lo_Max. The Hi_Max smoothing capacity shall be located somewhere after the Elasticity Buffer function in each repeat path through a station. If a MAC requiring nine or more preamble symbols to copy frames properly is configured in a repeat path, then the total required smoothing capacity shall be located between the Elasticity Buffer function and the MAC Receiver in that path.

The Smoothing function shall be capable of reclaiming additional space from stripped partial frames. This space may be reclaimed by deleting frame symbols or by replacing them with Idles. In addition, the Smoothing function may optionally reclaim space from other partial frames, provided that format errors are not lost. A format error is not lost if, either it is counted in PHY and reported to SMT, or it is correctly propagated to the next MAC or Repeat Filter function. After a token or partial frame, the Smoothing function may optionally delete excess symbols from preambles longer than four symbols.

If the Smoothing function is implemented before line state detection, then it shall not:

(a) Cause improper detection of ILS as a result of inserting Idle symbols when not in ILS or ALS

(b) Prevent proper detection of QLS, HLS, MLS, NLS, or LSU as a result of deleting symbols that are potential noise events

Given that a preamble consists of Idle symbols in the absence of noise, it is possible to relax some constraints on preamble processing with minimal impact on reliability. Specifically, during preamble processing the Smoothing function is not required to:

(a) Insert Idle symbols into a preamble except after four consecutive Idle symbols are received

(b) Delete non-Idle symbols from a preamble

8.3.1 Smoother State Machine

Figure 3 shows the Smoother function expressed as a state diagram. In the state diagram, states are shown as vertical staffs and state transitions as horizontal arrows, with the triggering event or condition above the shaft and any action beneath the shaft.

This state machine defines the operation of the Smoothing function implemented immediately before the PH_UNITDATA.indication interface. Any implementation that is interoperable with this state machine is permitted unless otherwise prohibited by this part of ISO 9314.

The state machine uses the following variables and parameters:

Hi_Max: The maximum smoothing capacity (in symbols) at the fourteen-symbol preamble threshold.

Hi_Ct: The current smoother extension (in symbols) at the fourteen-symbol preamble threshold. Byte-wide stations are permitted to count symbol pairs, rather than symbols (i.e., odd symbols can be ignored).

Lo_Max: The maximum smoothing capacity (in symbols) at the twelve-symbol preamble threshold.

Lo_Ct: The current smoother extension (in symbols) at the twelve-symbol preamble threshold. Byte-wide stations are permitted to count symbol pairs, rather than symbols (i.e., odd symbols can be ignored).

Out_Ct: The number of symbols output in the current state. Byte-wide stations are permitted to count symbol pairs, rather than symbols (i.e., odd symbols can be ignored).

T_Flag: Indicates that the current frame can not be stripped.

An implementation shall be permitted to maintain its counters and to adjust smoother extension and preamble length in quantum units of bits, symbols, or bytes (symbol pairs). This implies a corresponding restriction on the elasticity buffer, i.e., the elasticity buffer quantum shall not be larger than the maximum permitted smoother quantum (one byte).

8.3.1.1 State SM0:Preamble (PA)

In this state the Smoother function is processing preamble symbols. The smoother contracts when excess preamble symbols beyond the thresholds are processed. Out_Ct counts the number of output preamble symbols for threshold comparison. For interoperability, the smoother is not required to delete symbols in the exact sequence described by the PA_Actions nor to delete non-Idle symbols, provided that the counters are accurate upon exit from the PA state. If the smoother contracts at the twelve-symbol threshold, it is permitted, but not required, to also contract at the fourteen-symbol threshold during the same preamble.

SM(01):Start of SDU: When a Starting Delimiter (JK) symbol pair is detected as input, Start_Actions shall be performed and a transition to State SM1 shall occur. Start_Actions attempts to extend short preambles by inserting Idle symbols, with a corresponding expansion of the smoother. A symbol-wide implementation is permitted to trigger this transition when a J is received, but not when a J is internally duplicated (see 8.2.4, rule (e)). An implementation is permitted to use any threshold value between four and fourteen symbols when Start_Action is invoked after a Token or partial SDU (stripped SDU or format error).

8.3.1.2 SM1:Service_Data_Unit (SDU)

In this state the Smoother function is processing SDU (frame or Token) symbols. The smoother outputs all input symbols in this state. The T_Flag shall be set by the first occurrence of a non-data symbol. Out_Ct shall count the number of output SDU symbols, to ensure that End_Actions does not delete symbols prior to the start of the SDU.

SM(10):End of SDU: A transition to State SM0 shall occur when an Idle (I) symbol is detected as input. If the T_Flag is not set, indicating a stripped SDU, then End_Actions shall be performed to reclaim space by deleting previous SDU output symbols and contracting the smoother, or by replacing them with Idles without contracting the smoother. A byte-wide implementation shall trigger this transition when an Idle is detected as the first symbol of a symbol pair, and is optionally permitted to trigger this transition after an Idle is processed as the second symbol of a symbol pair. An implementation is permitted to trigger this transition for other input conditions that terminate the SDU (e.g., format errors or end of FS field), provided that End_Actions does not lose completed SDUs or format errors.

8.4 Repeat Filter

Certain station configurations require that PHY be able to repeat the PH_UNITDATA.indication symbol stream received on an inbound Physical Link directly as a PH_UNITDATA.request symbol stream on an outbound Physical Link without an intervening MAC entity (e.g., on the secondary logical ring without a second MAC in the station). In this situation, a Repeat Filter function is required somewhere after line state detection in the repeat path between the inbound Physical Link and the outbound Physical Link.

The repeat filter function prevents propagation of code violations and invalid line states from the inbound link to the outbound link, while permitting propagation of lost frames so they can be correctly counted by the next MAC entity in the logical ring. Although this function is not required when the station configuration includes a MAC entity in a logical ring, it may still be implemented in-line with the MAC entity without affecting correct ring operation.

Figure 4 shows the Repeat Filter expressed as a state diagram. In the state diagram, states are shown as vertical staffs and state transitions as horizontal arrows, with the triggering event or condition above the shaft and any action beneath the shaft.

The Repeat Filter shall change the symbol stream under the following rules:

(a) Following an I symbol, all subsequent symbols are changed into I symbols, until another I or a J symbol is encountered.

(b) If the symbol immediately after a J symbol is not a K symbol, then an implementation whose Elasticity Buffer and Decode functions can create duplicate J symbols (see 8.2.4) shall interpret the J symbol (not followed by a K symbol) as a V symbol (i.e., change the J symbol to an I or H symbol, depending on the current state). Other implementations are permitted to repeat the J symbol, or to interpret the J symbol or the next (non K) symbol as a V symbol.[1)]

(c) Following a JK symbol sequence, if another K symbol, any one of the possible H or V symbols, or a Q symbol is encountered, that symbol is changed into an H symbol. The

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[1)] This subclause is the intended subject of a future amendment to require that PHY interpret a received J symbol not followed by a K symbol as a Violation symbol.

next three symbols are also changed into H symbols unless a J or I symbol is encountered. After the fourth output H symbol, all subsequent symbols are changed into I symbols, until a J or I symbol is encountered. Note that this rule facilitates the correct counting of corrupted frames by the next MAC in the logical ring.

For a byte-wide (two-symbol) implementation of PHY, the following variations shall be permitted:

(a) State RF1:SD is not required since both the J and K symbols of a starting delimiter are aligned into the same byte by the Decode function. Thus, transitions may be made directly to state RF2:REPEAT from the other states upon receipt of a JK symbol pair.

(b) Transitions to RF0:IDLE shall be made from the other states when an I symbol is detected as the first symbol of a symbol pair; from state RF3:HALT after sourcing 4 Halt symbols (two Halt symbol pairs); and optionally after an I symbol is processed as the second symbol of a symbol pair.

(c) Otherwise, while in state RF2:REPEAT, if either symbol in the symbol pair is a J or K (with the exception of the JK starting delimiter pair), or a Q, H, or V, a transition to state RF3:HALT shall occur instead of repeating the symbol pair.

8.5 Ring latency

8.5.1 Minimum latency requirements

In the special case of a two-station ring composed of two PHYs (one in each station) and one MAC, a minimum ring latency of five octets is required to guarantee adequate preamble on a circulating token when the MAC is in repeat mode. This preamble is needed to ensure the proper operation of certain permitted implementations of the elasticity buffer in each PHY, while maintaining the integrity of the circulating token. The requirement for interoperability is that each station shall guarantee a minimum latency of three octets through the station when it configures a MAC in the repeat path, and a minimum latency of two octets when it does not configure a MAC in the repeat path.

8.5.2 Maximum latency calculation

Both MAC and SMT contain timers whose values are dependent on a deterministic upper bound on ring latency. Ring latency is the cumulative effect of alternating station delays and cable plant delays around the logical ring (as configured). The following parameters are used to calculate the upper bound on ring latency for use in setting timers:

SD_Min. Minimum Starting Delimiter Delay. This is the minimum propagation delay for a Starting Delimiter through a station when a JK is received in ILS, given that the elasticity buffer is at its theoretical minimum delay after processing an ILS to ALS transition (see 8.2.4, rule 1) and the smoother is fully contracted (see 8.3). The baseline value of SD_Min, for default D_Max calculation, is 74 bits (592 ns), measured at the station's Media Interface Connector (MIC).

SD_Max. Maximum Starting Delimiter Delay Contribution. This is the maximum contribution of individual station delay to the circulation delay for a Starting Delimiter around the logical ring. Individual station delay is the sum of:

SD_Min + sampling and timing error
+ quantizing error
+ smoother expansion

Although individual stations may have large smoother expansions, the smoothing algorithm limits the total smoothing expansion of the ring to less than ten bits per station. The combined elasticity buffer and smoother quantizing error is also limited to ten bits. Allowing 4 ns for sampling and timing error gives:

SD_Max ≤ 592 + 4 + 80 + 80
≤ 756 ns

The baseline value of SD_Max, for default D_Max calculation, is 756 ns, defined at the station's Media Interface Connector (MIC).

P_Max. Maximum number of Physical Layer entities. This is the maximum number of Physical Layer (PMD and PHY) entities configured in a logical ring, i.e., the number of station attachment points (MICs) in the ring. The default value for P_Max shall be 1 000 Physical Layer entities. Assuming that each Dual Attachment Station has two peer Physical Layer entities, and that each Single Attachment Station has a slave Physical Layer entity connected to a master Physical Layer entity in a concentrator, the default value can support rings of 500 stations.

D_Max. Maximum Ring Latency. This is the maximum circulation delay for a Starting Delimiter around the logical ring in the absence of noise. D_Max consists of the total station delay of all stations, plus the total propagation delay through the cable plant. Allowing for 100 km of duplex fibre cable in the logical ring, with a propagation delay of 5 085 ns/km, gives:

D_Max ≤ (P_Max x SD_Max)
+ (2 x 100 x 5 085)
≤ 756 000 + 1 017 000
= 1 773 000 ns
≤ 1,773 ms

The default value for D_Max shall not be greater than 1,773 ms. This value may be met by any combination of station delay and cable plant delay.

NOTE – Currently, the International Standard on FDDI MAC (ISO 9314-2) specifies that the default value for TVX shall be at least 62 500 symbol times (2,50 ms). Given the above rules for calculating D_Max, the value in that part of ISO 9314 should be interpreted as 2,500 rather than 2,50 ms. (The theoretical value is 2,498 660 ms. Assuming ±16 symbols timer quantizing error and ±50 ppm timer accuracy, the timer value would become 2,499 425 ms.)

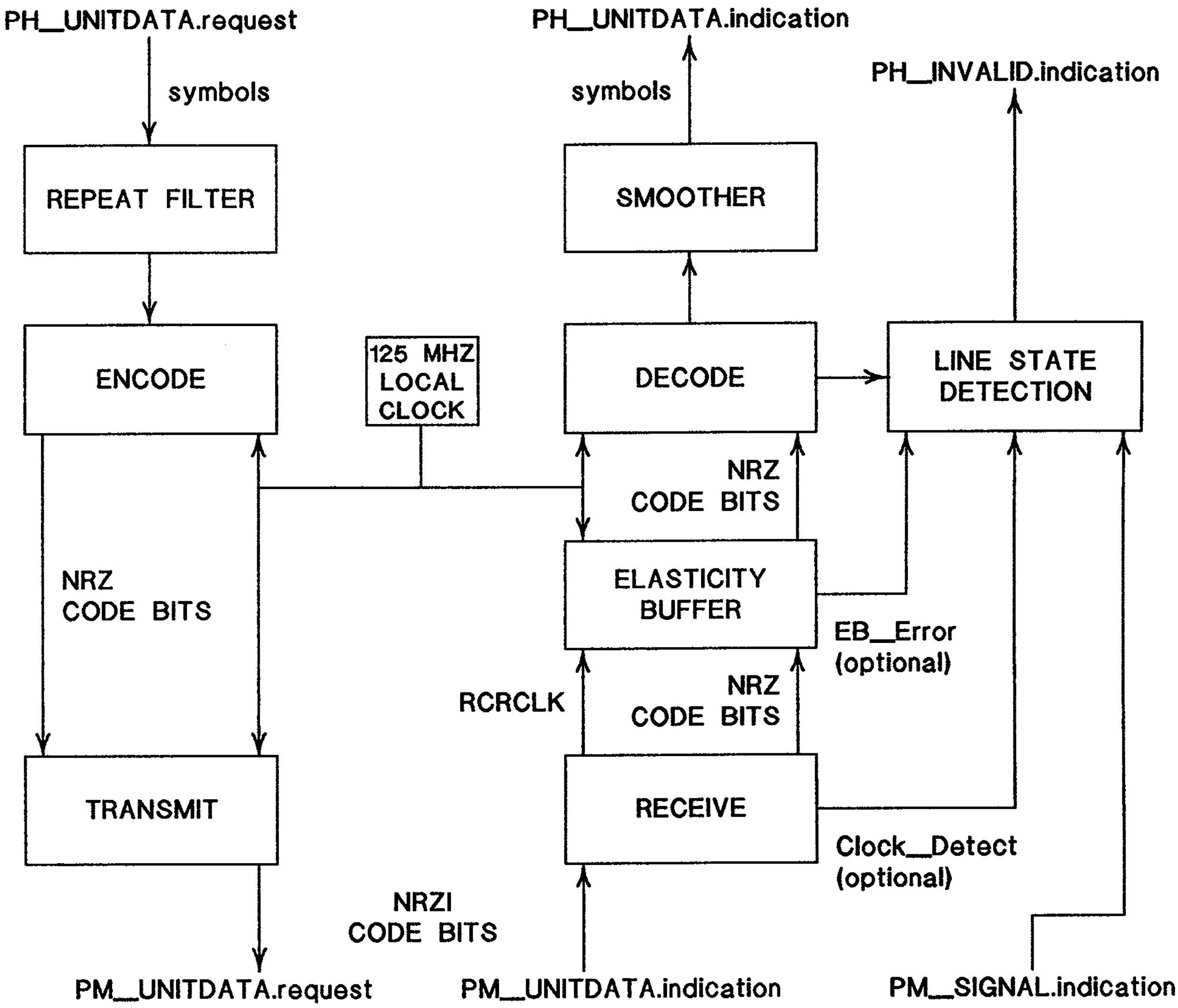
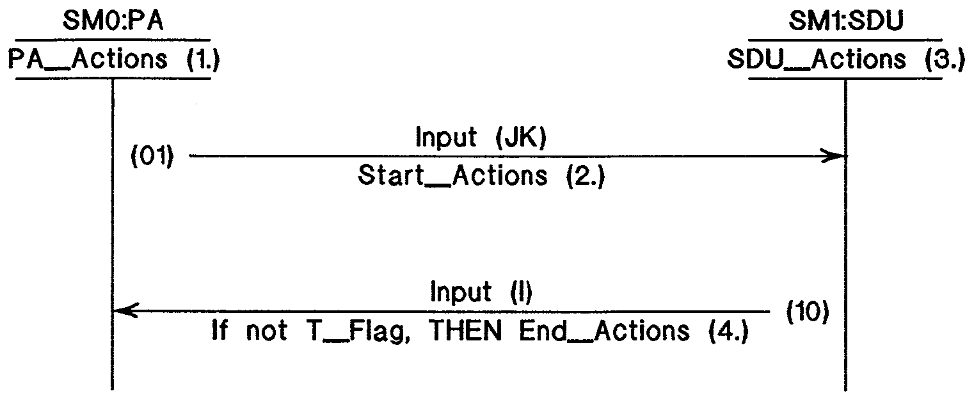


Figure 2 - An example of a FDDI PHY functional block diagram

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1. PA_Actions:
      CLEAR Out_Ct
      FOR EACH Input(symbol) DO
           IF Out_Ct = 12 & Lo_Ct > 0
              THEN DEC Lo_Ct
              ELSE IF Out_Ct = 14 & Hi_Ct > 0
                      THEN DEC Hi_Ct
                      ELSE Output(Input(symbol)); INC Out_Ct

2. Start_Actions:
      WHILE Out_Ct < 14 & Hi_Ct < Hi_Max DO
           Output(Idle); INC Out_Ct; INC Hi_Ct
      WHILE Out_Ct < 12 & Lo_Ct < Lo_Max DO
           Output(Idle); INC Out_Ct; INC Lo_Ct

3. SDU_Actions:
      Output(JK); SET Out_Ct = 2; Clear T_Flag;
      FOR EACH Input(symbol) DO
           Output(Input(symbol)); INC Out_Ct;
           IF (Input(not n))
              THEN SET T_Flag

4. End_Actions:
      REPEAT x TIMES, where min(2,Lo_Ct+Hi_Ct) ≤ x ≤ Out_Ct
          (SET previous Output(symbol) = Idle) or
          (Remove previous Output(symbol);
           IF Lo_Ct > 0
              THEN DEC Lo_Ct
              ELSE IF Hi_Ct > 0
                      THEN DEC Hi_Ct)
```

Figure 3 – Smoother state diagram

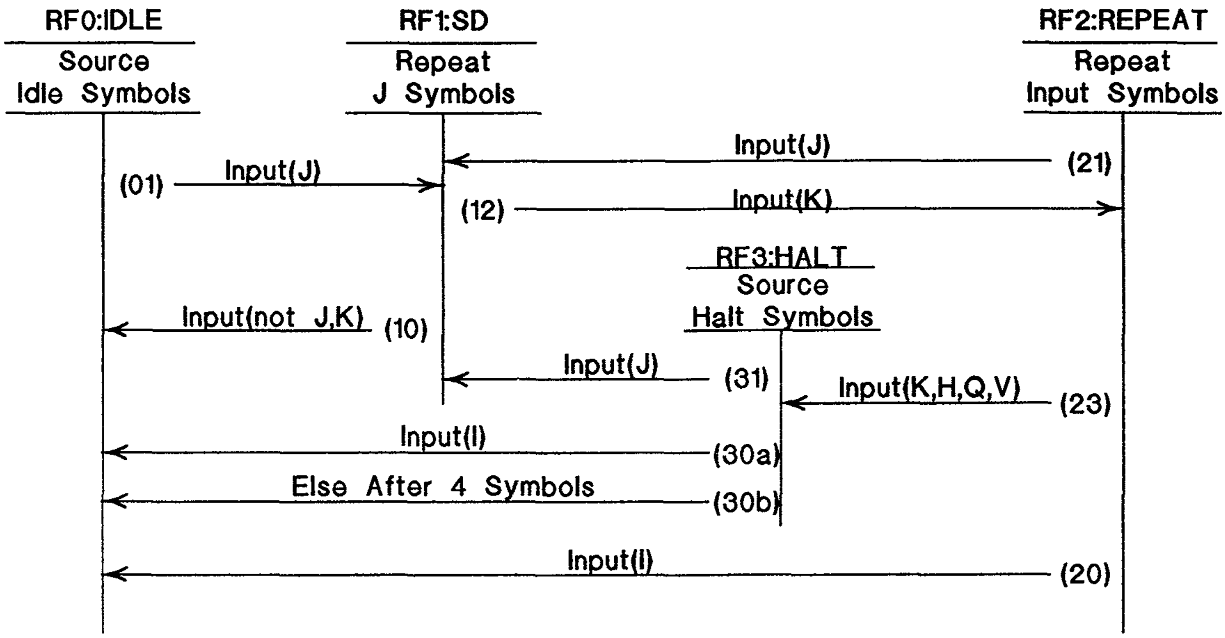

Figure 4 - Repeat filter state diagram

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