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# IEEE-1394b
# Interface Requirements for
# Military and Aerospace Vehicle Applications

RATIONALE

In the original release of AS5643, the priority values for word 3 of the ASM header are opposite what they should be. This occurred because of an error in the FC-AE-ASM draft document that was referenced. This limited scope revision to AS5643 references the recently-released FC-AE-ASM document and provides the necessary corrections to the priority values for word 3 of the ASM header.

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# 1. SCOPE

This SAE Aerospace Standard (AS) establishes the requirements for the use of IEEE-1394b as a data bus network in military and aerospace vehicles. It defines the concept of operations and information flow on the network. As discussed in 1.4, this specification contains extensions/restrictions to “off-the-shelf” IEEE-1394 standards, and assumes that the reader already has a working knowledge of IEEE-1394.

This document is referred to as the “base” specification, containing the generic requirements that specify data bus characteristics, data formats and node operation. It is important to note that this specification is not stand-alone - several requirements provide only example implementations and delegate the actual implementation to be specified by the network architect/integrator for a particular vehicle application. This information is typically contained in a “network profile” slash sheet that is subsequent to this base specification. In a similar manner, the electrical characteristics of the bus media, as well as connector information is contained in a “physical layer” slash sheet, that also may be unique to a particular vehicle application.

In summary, full understanding of this specification requires knowledge of IEEE-1394b standards and access to the physical layer slash sheets and the slash sheets and handbook for the target application.

## 1.1 Purpose

The purpose of this document is to standardize an approach to using IEEE-1394 in safety-critical/mission-critical applications for military and aerospace vehicles. The information herein will be used to assist the design, fabrication, and maintenance of the nodes that interface via the vehicle’s network.

This document is controlled and maintained by the SAE with technical support from Remote Node vendors.

## 1.2 Application

The IEEE-1394 Network defined in this document provides a deterministic, rate based communication protocol overlaid on the existing IEEE-1394 standard capabilities.

## 1.3 Interpretation

The following interpretations shall be placed upon these words, unless stated otherwise, where they are used in this document.

May: An allowed action.
Shall: A mandatory requirement.
Should: A recommended action.
Will: A declaration of intent.

## 1.4 Additions to the IEEE-1394, IEEE-1394a, and IEEE-1394b Standards

Additions include the use of asynchronous stream packets, a fixed frame rate synchronized with a Start Of Frame packet, addition of a Vertical Parity Check, static assignment of channel numbers, pre-assignment of bandwidth, and use of Anonymous Subscriber Messaging.

### 1.4.1 Use of Asynchronous Streams

Asynchronous streams are used for most communication on the network. Asynchronous and isochronous packets are not required but may be utilized. Architectures and protocols discussed in the context of this document are based on asynchronous streams, unless it is otherwise mentioned. An example of using asynchronous packets would be to allow test equipment to read data from a Configuration ROM. An example of using isochronous packets would be for streaming video and/or audio.

### 1.4.2 A Fixed Frame Rate

If isochronous packets are not utilized, there is no requirement for Cycle Start packets to be sent at the normal 125-microsecond rate. Instead, this implementation provides a fixed frame rate for synchronization of the network. If isochronous packets are utilized, it is necessary to utilize the Cycle Master function so the 125-microsecond periodic cycle starts are available to isochronous sources that expect them. Figure 18 in 3.3.3.3 shows an example of interleaving isochronous packets and asynchronous stream packets.

### 1.4.3 Synchronization Via Start of Frame Packets

A Start Of Frame (STOF) packet is transmitted by the Control Computer on each bus at a periodic (e.g. 100 Hertz) frame rate. This packet informs all nodes on the bus that a new frame has started.

### 1.4.4 Static Assignment of Channel Numbers

Because asynchronous stream packets are, in reality, isochronous packets, the destination of the packet is identified by a channel number. Unlike standard 1394, the channel numbers for destination nodes are not assigned by an Isochronous Resource Manager (IRM). Instead, the channel numbers for each node on the bus are pre-assigned, are application specific, and will be defined as required by the architecture.

### 1.4.5 Pre-Assignment of Bandwidth

The lack of an IRM requires that bandwidth be pre-assigned, also. Transmit and receive times for each node on the bus are assigned as offsets, in increments of 1 microsecond, from the start of each frame (STOF packet). The offsets for each node on the bus are application specific and will be defined as required by the architecture.

### 1.4.6 Vertical Parity Check

Vertical Parity Checking (VPC) is performed on the data area of each packet as an adjunct to the Cyclic Redundancy Check (CRC) performed by the 1394 physical layer devices. The VPC provides additional data integrity as the messages progress through the physical and software layers.

### 1.4.7 Anonymous Subscriber Messaging

Anonymous Subscriber Messaging (ASM) is a protocol, in which, a Remote Node on the network can subscribe to each message that it requires. The ASM software in the Remote Node will forward only the messages to which the Remote Node has subscribed.

ASM is an upper level protocol tailored for the demands of highly modular embedded real time systems operating under a “data push paradigm. ASM is designed to be independent of lower level protocols and, as such, does not utilize the 1394 header to transport ASM-peculiar information. ASM is tailored to support deterministic, secure, low-latency communication between processors, sensors, instrumentation, and displays in mission-critical applications. It uses Message IDs to decouple the network traffic from physical addresses so application software can communicate without knowledge of network topology.

## 2. DEFINITIONS AND APPLICABLE DOCUMENTS

### 2.1 Definitions

ASM HEADER: Anonymous Subscriber Messaging Header, the header that contains information relevant to the node transmitting the data and the communication status of that node.

ASYNCHRONOUS: (1) pertaining to a transmission technique that does not require a common clock between the communicating devices. Timing signals are derived from special characters in the data stream itself. (2) not synchronous, not occurring or existing at the same time or having the same period or phase.

ASYNCHRONOUS STREAM PACKET: An isochronous packet that occurs in the fairness interval or asynchronous time frame. Data transmission is carried out in accordance with asynchronous arbitration rules; however, there is no acknowledge packet or response returned by the targeted node.

ASYNCHRONOUS TRANSACTION: A transaction carried out in accordance with asynchronous arbitration rules. The transaction is always a request/response transaction and provides an acknowledgement of data delivery.

BER: Bit Error Rate is a parameter relating to the quality of a serial transmission system. BER is the percentage of bits having errors, relative to the total number of bits received in a transmission. BER is usually expressed as ten to a negative power.

BIG ENDIAN: Describes a memory-addressing architecture in which, within a given multi-byte numeric representation, the most significant byte has the lowest address (the word is stored 'big-end-first'). Big-endian byte order is also sometimes called 'network order'.

BRANCH: A node physically connected to two or more nodes (i.e. two or more ports are connected).

BUS: One of the 1394 trees connected to each CC Branch.

BUS MANAGER: One node residing on the bus may be selected to provide serial bus services for the benefit of the community of all nodes residing on the bus.

CC: Control Computer. The CC is the root node, Cycle Master (if used), and Bus Manager for its respective data bus.

CC-BRANCH: One set of redundant resources (e.g. a CC including all of its buses and Remote Node).

CHANNEL/CHANNEL NUMBER: The means by which Isochronous and Asynchronous Stream packets are addressed. Data is transmitted onto the bus with a particular channel number. Nodes on the bus wishing to receive the data are configured to accept packets addressed with that channel number.

CORBA: **C**ommon **O**bject **R**equest **B**roker **A**rchitecture, OMG's open, vendor-independent architecture and infrastructure that computer applications use to work together over networks. Using the standard protocol IIOP, a CORBA-based program from any vendor, on almost any computer, operating system, programming language, and network, can interoperate with a CORBA-based program from the same or another vendor, on almost any other computer, operating system, programming language, and network.

CRC: Cyclic Redundancy Check – a 'check summing' algorithm generated and verified by the 1394 hardware.

CYCLE MASTER: The node that generates the periodic (125µs) cycle start packet.

DATA PUMP: Internal equipment software parameters or memory values placed on the bus to support integration and test.

FRAME: The time interval between consecutive STOF messages (e.g. 10.0 milliseconds).

ISOCHRONOUS: Uniform in time (i.e. having equal duration) and recurring at regular intervals. A form of data transmission that guarantees to provide a certain minimum data rate, as required for time-dependent data such as video or audio. Isochronous transmission transmits asynchronous data over a synchronous data link so that individual characters are only separated by a whole number of bit-length intervals. This is in contrast to asynchronous transmission, in which the characters may be separated by arbitrary intervals, and with synchronous transmission.

ISOCHRONOUS RESOURCE MANAGER: The node that maintains the channels available, bandwidth available, and bus manager ID registers.

ISOCHRONOUS TRANSFER: A data transmission method that occurs uniformly in time and recurs at regular intervals (integer multiple of 125 µs).

LEAF: A node physically connected to only one other node (i.e. only one port is connected).

LINK LAYER: The serial bus layer that defines the data transfer services. It also provides addressing, data checking, and data framing.

LRC: Line Replaceable Component.

LRU: Line Replaceable Unit.

MESSAGE: Unlike the classic definition of a message, this implementation limits a message to the amount of data that may encompass only one packet.

NODE: An addressable device attached to the Serial Bus with at least the minimum set of control registers. Changing the control registers on one node does not affect the state of control registers on another node. A node may have one or more ports.

NODE ID: A 16-bit number (10-bit bus address/6-bit node address) that uniquely identifies a node. The node ID can change subsequent to a bus reset.

PAYLOAD: The useful information or data contained within a message (e.g. that portion of the packet data area exclusive of the ASM Header and the Vehicle Trailer).

PORT: A physical layer entity in a node that connects to a cable and provides one end of a physical connection with another node.

PHY LAYER: The serial bus physical layer that translates the logical symbols used by the link layer into electrical signals on serial bus media. The PHY is also responsible for performing the arbitration tasks for a node to gain access to the bus.

QUADLET: Four bytes, or 32 bits of data.

REMOTE NODE: A node, other than the CC, on a bus.

ROOT NODE: The node on the bus with the highest node ID. The root node is the Cycle Master and is responsible for resolving arbitration in IEEE-1394 buses. The root serves this function when in 1394a mode on a 1394b bus, but when a bus can do 1394b BOSS arbitration, it is the BOSS node (node currently transmitting) that grants the bus (resolves arbitration).

STOF: STart Of Frame. A packet sent by each CC at a periodic (frame) rate.

TRANSACTION: A request and the optional, corresponding response.

VPC: Vertical Parity Check. A secondary verification of data within a packet.

XOR: Exclusive-OR.

XOR-ed: Exclusive-ORed.

## 2.2 Government Documents

The following government documents form a part of this document to the extent specified herein.

None Identified.

## 2.3 Non-Government Documents

The following non-government documents form a part of this document to the extent specified herein.

| | |
|---|---|
| IEEE Std 1394-1995 | IEEE Standard for a High Performance Serial Bus |
| IEEE Std 1394a-2000 | IEEE Standard for a High Performance Serial Bus, Amendment 1 |
| IEEE Std 1394b-2002 | IEEE Standard for a High Performance Serial Bus, High Speed Supplement |
| IEEE Std 754 | IEEE Standard for Binary Floating-Point Arithmetic |
| IEEE Std 1212-2001 | IEEE Standard for a Control and Status Register (CSR) Architecture for Microcomputer Busses |
| INCITS TR-41-2006 | INCITS Technical Report for Information Technology - Fibre Channel – Avionics Environment – Anonymous Subscriber Messaging (FC-AE-ASM) |

## 2.4 Applicable References

Firewire System Architecture, Second Edition, IEEE 1394a, Mindshare, Inc., 1999

# 3. IEEE-1394B REQUIREMENTS

The requirements are based on the IEEE Standard for a High Performance Serial Bus (IEEE-1394-1995), Amendment One (IEEE-1394a-2000), and High-Speed Supplement (IEEE-1394b-2002). This section delineates the options selected and interprets any ambiguities.

## 3.1 Data Bus Architecture and Operation

The network functions synchronously using the asynchronous stream packets of IEEE 1394 operation. Transmission occurs in a ”dual simplex” manner; packets can be transmitted on the TPB pair at the same time arbitration and or signaling is received on the TPA pair and packets can be received on the TPA pair at the same time arbitration is transmitted on the TPB pair. Control of information transmission resides with the individual nodes on the bus.

Data transmission on the bus shall be composed primarily of Asynchronous Stream Packets, as defined in 3.3.3.1. In addition, asynchronous and isochronous packets, as defined in 3.3.3.2 and 3.3.3.3 may be utilized as necessary. The representative Remote Nodes’ Subsystem IDs and Channel Numbers are defined in 4.1.

The network shall implement a physical layer based on the IEEE-1394b-2002 signaling standard. This standard provides automatic detection and breaking of loops. Implementing a loop enhances redundancy by providing an alternate path to a node when another node on the bus fails. For example, in Figure 2, if CC-Branch Node 4 should fail, the CC can still access CC-Branch Node 5 and CC-Branch Node 3 via its two separate ports.

The 1394 data bus may typically be configured with several independent buses connecting the nodes. The following sections illustrate different network configurations.

### 3.1.1 Basic Network Architecture

Figure 1 illustrates a basic network architecture with a single Control Computer (CC). Even though each of the three ports of the CC has Remote Nodes attached, it comprises a single IEEE-1394 bus.

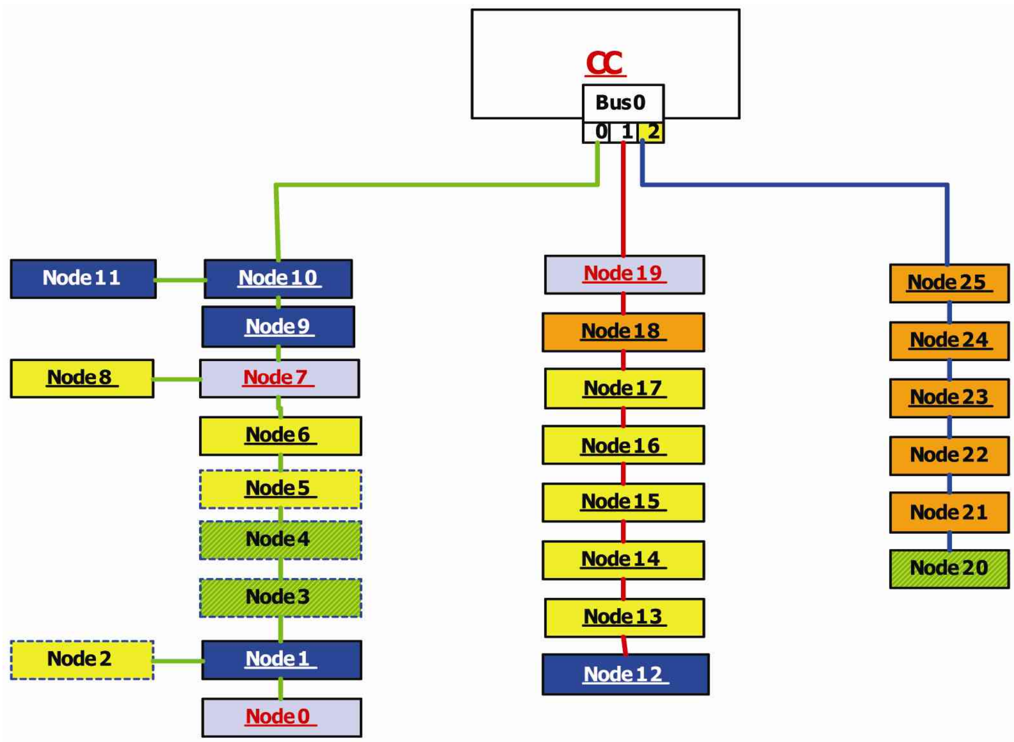


FIGURE 1 - BASIC NETWORK WITH SINGLE CC
COLORS, SHADING, AND OUTLINES COULD INDICATE DIFFERENT TYPES OF NODES ON THE BUSSES

### 3.1.2 Basic Network Architecture With a Loop

Figure 2 illustrates a basic network architecture utilizing a single CC and a loop created by connecting Node 0 back to port 1 of the CC. Loops are not allowed in IEEE-1394 and IEEE-1394b PHYs will automatically detect and break the loop. Exactly where the loop is broken is unknown until the new architecture tree has been configured. After the PHYs break the loop there will be two trees, one on port 0 and the other on port 1. If a node on either port should now fail, the bus will automatically reconfigure with the failed node on the "end" of one of the trees. All other nodes will still be enabled. This provides the first level of redundancy.

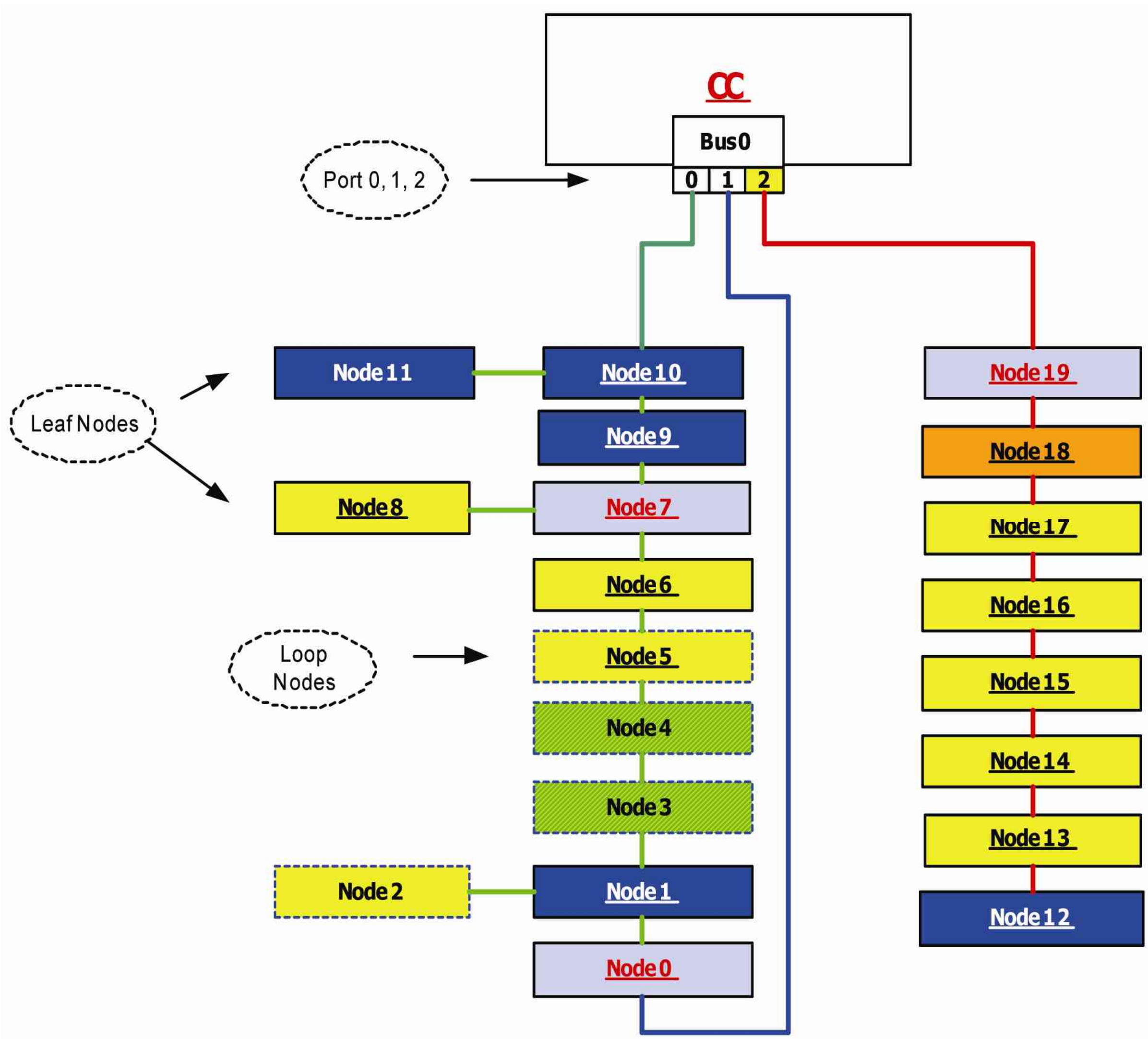


FIGURE 2 - BASIC NETWORK WITH SINGLE CC AND A LOOP
COLORS, SHADING, AND OUTLINES COULD INDICATE DIFFERENT TYPES OF NODES ON THE BUSSES

3.1.3 Representative Triplex Network Architecture With Loops

Figure 3 illustrates an architecture for a representative triplex 1394 vehicle network. The three CCs have been cross-channel linked, thus providing another level of redundancy.

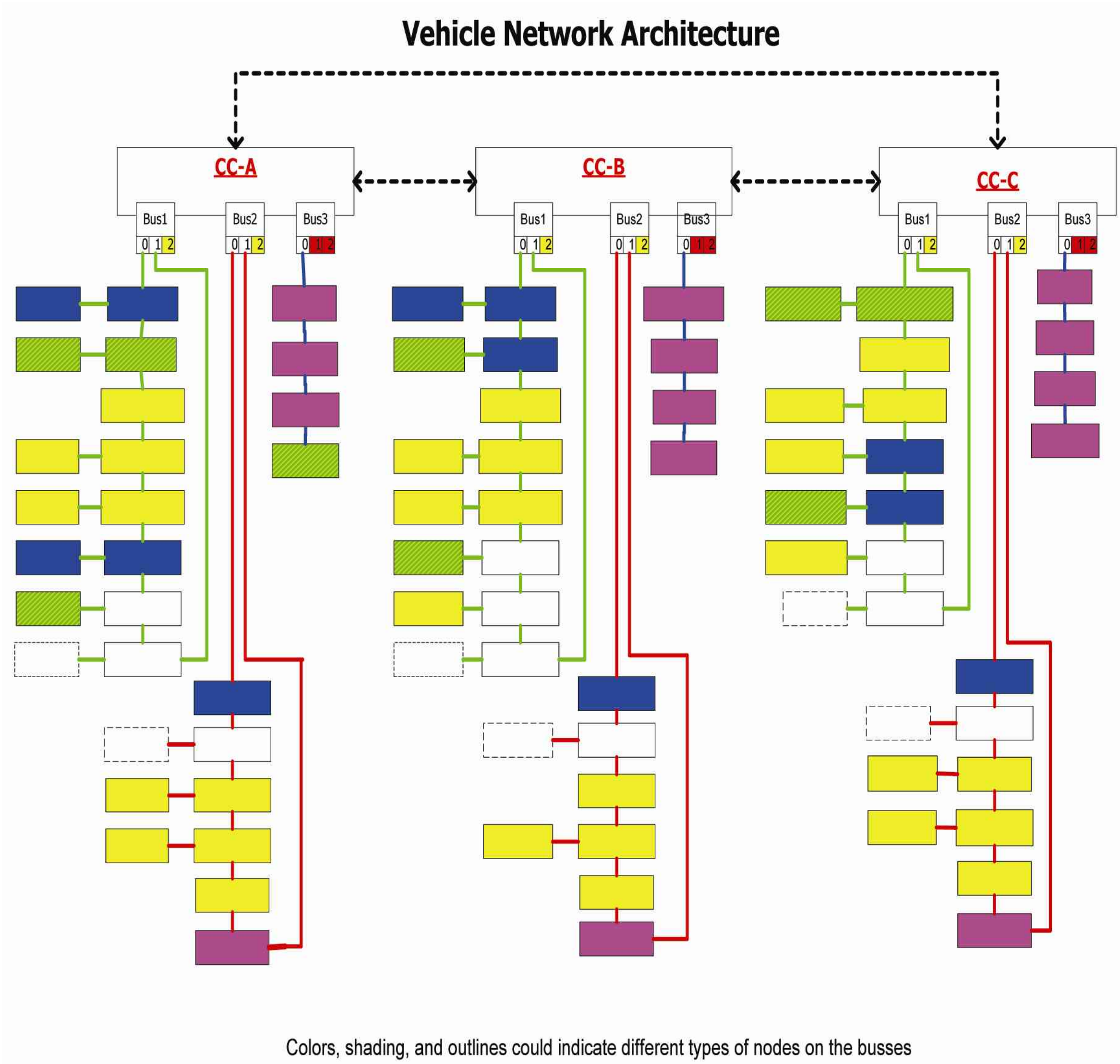


FIGURE 3 - REPRESENTATIVE TRIPLEX CC ARCHITECTURE

## 3.2 Data Bus Characteristics

### 3.2.1 Data Format

Digital data may be transmitted in any supported form. All data on the bus shall be quadlet (32-bit word) aligned. All floating-point numbers shall be compliant with IEEE-754 floating-point format. Packets, also, shall be quadlet (32-bit word) aligned and must end with a quadlet (32-bit aligned word).

Refer to Table 1 for size definitions of the supported data types. This includes CORBA standard data types.

TABLE 1 - SUPPORTED DATA TYPES

| Data Type | Data Type Description | Bit Length |
|---|---|---|
| Boolean Bit | Boolean Bit | 1 |
| Very Short Enumerated | Very Short Enumerated | 8 |
| Character | Character | 8 |
| Boolean Byte | Boolean Byte | 8 |
| Signed Very Short Integer | Signed Very Short Integer | 8 |
| Unsigned Very Short Integer | Unsigned Very Short Integer | 8 |
| Short Packed Boolean | Short Packed Boolean | 16 |
| Short Enumerated | Short Enumerated | 16 |
| Signed Short Integer | Signed Short Integer | 16 |
| Unsigned Short Integer | Unsigned Short Integer | 16 |
| Long Enumerated | Long Enumerated | 32 |
| Long Packed Boolean | Long Packed Boolean | 32 |
| Signed Long Integer | Signed Long Integer | 32 |
| Unsigned Long Integer | Unsigned Long Integer | 32 |
| IEEE Floating Point | IEEE Floating Point | 32 |
| Variable Length Data Stream | Variable Length Data Stream | 32 |
| Unicode | Unicode | 32 |
| String | ASCII Character String | 32 |
| Signed Long Long Integer | Signed Long Long Integer | 64 |
| Unsigned Long Long Integer | Unsigned Long Long Integer | 64 |
| IEEE Double Floating Point | IEEE Double Floating Point | 64 |

### 3.2.2 Bit Ordering

All data (bytes and bits) transmitted on the 1394 Network shall be in big endian format.

In big-endian format, bit 0 is the most significant bit (msb) and bit 31 is the least significant bit (lsb). Figure 4 depicts the two bit-ordering schemes.

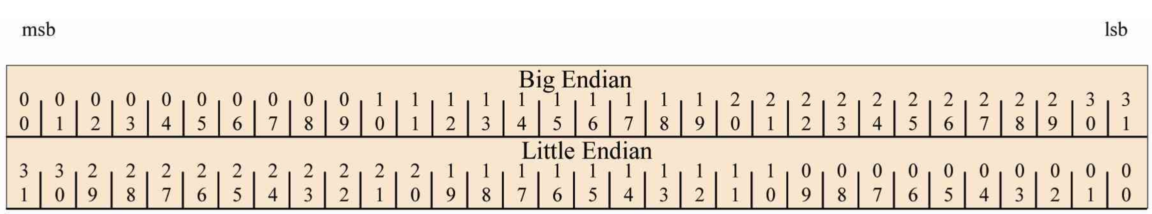


FIGURE 4 - BIT ORDERING

### 3.2.3 Transmission Method

#### 3.2.3.1 Transmission Bit Rate

Transmission bit rates of S100 (100 Mbps), S200 (200 Mbps), S400 (400 Mbps), S800 (800 Mbps), S1600 (1600 Mbps), and S3200 (3200 Mbps) are permitted and may be supported, as defined in the physical layer slash sheets and the slash sheets and handbook for the target application.

#### 3.2.3.2 Packet Size

The maximum packet size for a given asynchronous stream transmission bit rate shall be set consistent with that specified in the IEEE-1394 specification. Refer to 3.2.4.1.8 for limitations on this size.

### 3.2.4 IEEE 1394 Packet Formats

The data packet format shall conform to the IEEE-1394 standard. The supported packet formats are shown in following sections.

#### 3.2.4.1 Asynchronous Stream Packets

Asynchronous stream packets are isochronous packets that are normally sent during the asynchronous time interval. Figure 5 shows a typical asynchronous stream packet as seen on the bus. These packets, as defined in this specification, consist of the 1394 header, inserted by the hardware, the Anonymous Subscriber Messaging Header, the Payload Data Area, the Packet Trailer, and the 1394 CRC, inserted by the hardware.

##### 3.2.4.1.1 Data Length

The Data Length field shall specify the number of data bytes in the packet. This includes the ASM Header, Payload Data, and Packet Trailer. This shall be an Unsigned Short Integer (16 bits). The number of actual data bytes in the Payload Data area can be determined by subtracting the size of the ASM Header (16 bytes) and the size of the Packet Trailer (16 bytes) from the Data Length field.

##### 3.2.4.1.2 Tag

The Tag field indicates the format of data carried by isochronous packets (00 = formatted, 01 – 11 are reserved). This field shall be set to zero (00).

##### 3.2.4.1.3 Channel

The Channel field shall identify the destination of the asynchronous stream. An example of remote node channel number assignments is defined in 4.1.

##### 3.2.4.1.4 Tcode

The Tcode shall be set to 1010 binary to identify the asynchronous stream packet type.

##### 3.2.4.1.5 Sy

The Sy field is unused and shall be set to zero (0).

##### 3.2.4.1.6 Header CRC/Data CRC

The Header and Data CRC fields are generated by the IEEE-1394 link layer. Refer to the IEEE-1394-1995 specification for the CRC algorithm.

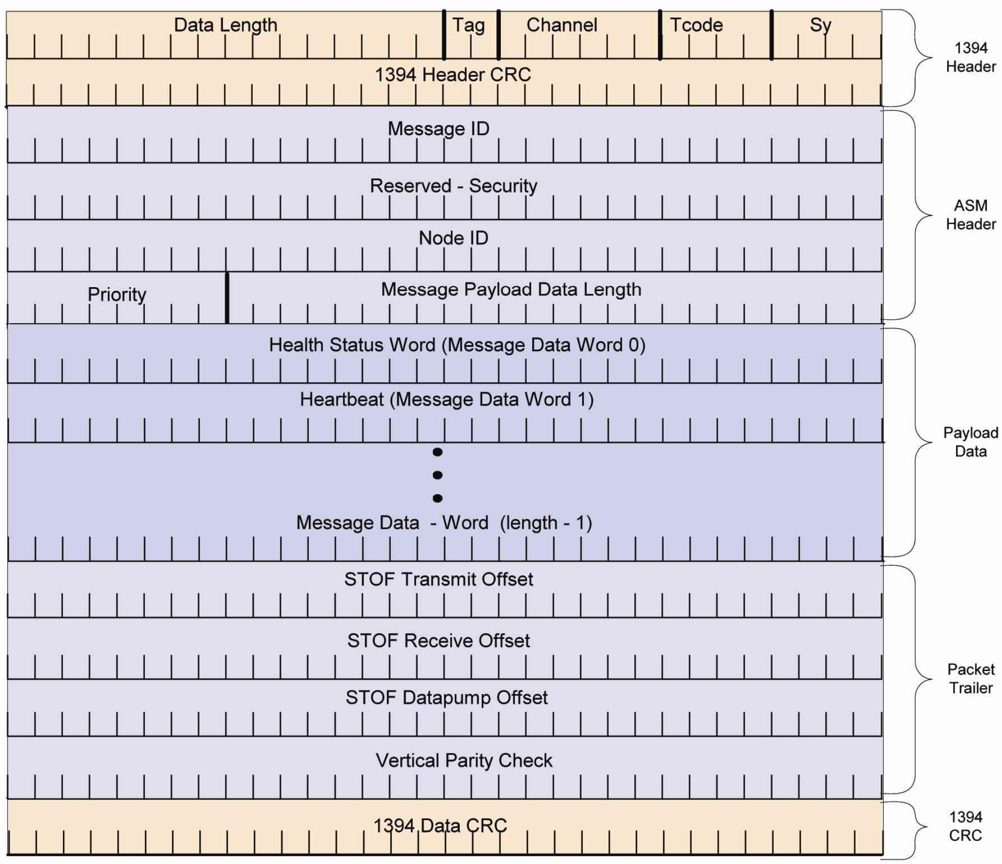


FIGURE 5 - ASYNCHRONOUS STREAM PACKET

3.2.4.1.7 ASM Header

Every asynchronous stream packet on the bus containing the Packet Data area shall be transmitted with the ASM Header as the first four (4) 32-bit quadlets of the data payload. The ASM Header shall conform to Figure 6.

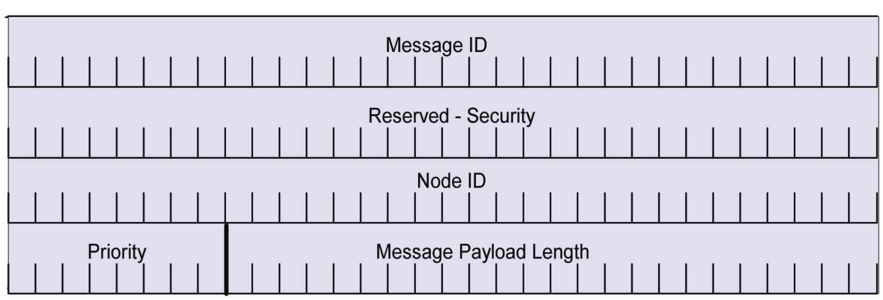


FIGURE 6 - ASM HEADER

3.2.4.1.7.1 Message ID

Word 0 of the ASM Header shall contain the Message ID (Unsigned Long Integer format with a resolution of 1). The Message ID shall be a 32-bit pattern that uniquely identifies the message. Refer to 3.2.4.1.7.2 for the Message ID bit definition.

This requirement also applies to "redundant" 1394 nodes operating on different CC channels. For example, assume that LRU #1 on the CC-A network and LRU #2 on the CC-C network have identical load images that produce the same 1394 output message. The LRU #1 message will have a Message ID different from the LRU #2 Message ID, even though the data content is identical. This applies to LRU inputs as well as outputs. As a result, the LRUs will require some knowledge or input to determine whether they are #1 or #2.

3.2.4.1.7.2 Message ID Digits

The Message ID shall be a 32-bit number represented as an unsigned long integer. An example might be to utilize a decimal number with the first two digits of the Message ID used to identify the CC branch the message originates from: 01=Branch A, 02=Branch B, 03=Branch C, etc. This provides for up to 41 branches. The next two digits might represent the channel number of the Logical Subsystem (1394 is limited to 63 channels). The remaining six digits might represent the message number from 00-999,999 for a total of 1,000,000 messages per Logical Subsystem. Further details should be documented in the network profile slash sheet for the target application.

3.2.4.1.7.3 Security

Word 1 of the ASM Header shall contain the Security field. A value of zero (0) indicates the lowest level of security. Security is not required but may be utilized by each Remote Node as desired. The Security field shall be set to zero (0) if it is not used.

3.2.4.1.7.4 Node ID

Word 2 of the ASM Header shall contain the IEEE-1394 Node ID (Unsigned Long Integer format with a resolution of 1) that is reported by the PHY device of that node. This is a 16-bit number that uniquely differentiates a node from all other nodes within a group of interconnected buses. The 10 most significant bits (MSBs) of the node ID are the same for all nodes on the same bus; this number is the bus ID. The 6 least significant bits LSBs of the node ID are unique for each node on the same bus; this number is called the physical ID. The physical ID is assigned as a consequence of bus initialization.

3.2.4.1.7.5 Priority

The most significant bit of the most significant byte of word 3 (the "L" bit as defined in FC-AE-ASM) shall be set to zero and is not used. The remaining bits of the most significant byte of word 3 shall contain the optional Message Priority field. A value of '0000000' b in these bits shall indicate that no Priority has been assigned to the frame. The remaining values shall indicate, in ascending order, the relative priority of the frame (e.g., a Priority of hex '23' shall be considered to have a lower priority than a Priority of hex '57').

3.2.4.1.7.6 Payload Length

The least significant three (3) bytes of word 3 shall contain the Payload Length (Unsigned Short Integer word format with a resolution of 1). The Payload Length shall be the number of bytes in the entire message associated with the Message ID.

Payload Length calculation does not include the ASM Header or the Packet Trailer, but does include the Heartbeat and the Health Status Word. Therefore, the maximum payload data size is 32 bytes less than the maximum specified in the IEEE-1394b-2002 specification and the minimum payload data size is eight (8) bytes (the Heartbeat and Health Status words). The actual message data size is limited due to the inclusion of the Heartbeat and Health Status words.

Because the message size is limited, only the least significant two (2) bytes of the Payload Length shall be used. The third byte shall be filled with zeros. This shall be an Unsigned Short Integer (16 bits). Refer to 3.2.4.1.8 for the Payload Data Area contents.

3.2.4.1.8 Payload Data Area

The Payload Data area starts with Word 2 in the Asynchronous Stream Packet Data area. Refer to 3.2.1 for acceptable data types. All payload data shall be 32-bit aligned data. Figure 7 Illustrates the contents of the packet data area.

To satisfy the message size requirement, the actual payload data size must be limited. The ASM Header (4 quadlets), the Packet Trailer (4 quadlets), the Health Status Word (1 quadlet), and Heartbeat (1 quadlet) must be subtracted from the maximum packet size specified in the IEEE-1394b-2002 specification. This allows a maximum message length 10 quadlets less than the specified maximum.

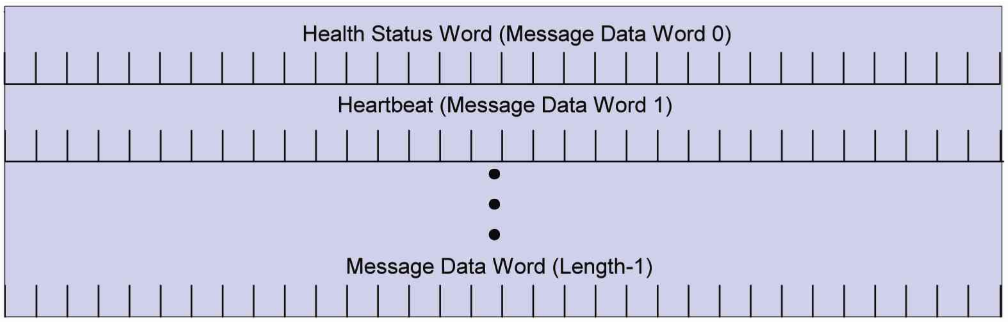


FIGURE 7 - PAYLOAD DATA AREA

3.2.4.1.8.1 Health Status Word

Word 0 of the Packet Payload data area shall contain a Health Status Word. The Health Status Word shall be a 32-bit word (Long Packed Boolean). The Health Status Word shall contain, at a minimum, the following information:

- Packet Error
- Subsystem Error
- Node Error
- Status of each port on the node – Whether connected, if receiving OK, In Beta Mode or not, and Negotiated Speed

The following provides an example for formatting of the required status. Alternate assignments should be made to accommodate different organizations as defined in the network profile slash sheet for the target application.

- (LSB) Bit 31: Packet Error
- Bit 30: Subsystem Error
- Bit 29: Node Error
- Bit 28: STOF Offset Acknowledge
- Bit 27: Spare
- Bit 26: Spare
- Bit 25: Spare
- Bit 24: Spare

- Bit 23: Port 0 - Connected
- Bit 22: Port 0 - Receive OK
- Bit 21: Port 0 - Beta Mode
- Bit 20: Port 0 - Speed Bit 0
- Bit 19: Port 0 - Speed Bit 1
- Bit 18: Port 0 - Speed Bit 2
- Bit 17: Port 0 - Spare
- Bit 16: Port 0 - Spare
- Bit 15: Port 1 - Connected
- Bit 14: Port 1 - Receive OK
- Bit 13: Port 1 - Beta Mode
- Bit 12: Port 1 - Speed Bit 0
- Bit 11: Port 1 - Speed Bit 1
- Bit 10: Port 1 - Speed Bit 2
- Bit 09: Port 1 - Spare
- Bit 08: Port 1 - Spare
- Bit 07: Port 2 - Connected'
- Bit 06: Port 2 - Receive OK
- Bit 05: Port 2 - Beta Mode
- Bit 04: Port 2 - Speed Bit 0
- Bit 03: Port 2 - Speed Bit 1
- Bit 02: Port 2 - Speed Bit 2
- Bit 01: Port 2 - Spare
- (MSB) Bit 00: Port 2 - Spare

3.2.4.1.8.1.1 Message Error

The Message Error Bit shall be set to one if the preceding message between the nodes was received in error as defined in 3.3.1.2 for the CC and 3.3.2.4 for a Remote Node. Otherwise, the Message Error Bit shall be cleared to zero.

3.2.4.1.8.1.2 Subsystem Error

The Subsystem Error Bit shall be set to one to indicate a fault in the subsystem to which a node is connected. Otherwise, the Subsystem Error Bit shall be cleared to zero.

3.2.4.1.8.1.3 Node Error

The Node Error Bit shall be set to one to indicate a fault in the node. Otherwise, the Node Error Bit shall be cleared to zero.

3.2.4.1.8.1.4 STOF Offset Acknowledge

The STOF Offset Acknowledge bit shall be to set to one to indicate a Remote Node has received all of its STOF Offsets. If the Remote Node has not received all of its STOF Offsets, the STOF Offset Acknowledge bit shall be cleared to zero.

3.2.4.1.8.1.5 Port n - Connected

The Connected bit shall be set to one if the result of reading the PHY's Port Status Registers indicates that the port is connected. If the status indicates the port is not connected, the bit shall be cleared to zero.

3.2.4.1.8.1.6 Port n - Receive OK

The Receive OK bit shall be set to one if the result of reading the PHY's Port Status Registers indicates that the port is receiving. If the status indicates the port is not receiving, the bit shall be cleared to zero.

3.2.4.1.8.1.7 Port n - Beta Mode

The Beta Mode bit shall be set to one if the result of reading the PHY's Port Status Registers indicates that the port is in Beta Mode. If the status indicates the port is not in Beta Mode, the bit shall be cleared to zero.

3.2.4.1.8.1.8 Port n - Speed Bits 0-2

The Speed bits shall be set to the value read from the PHY's Port Status Registers speed bits. These bits indicate the speed, as defined in the IEEE-1394 specification, at which the port is operating. Refer to Table 2 for speed bit decoding.

TABLE 2 - SPEED BITS

| SPEED | Speed Bit 2 | Speed Bit 1 | Speed Bit 0 |
|---|---|---|---|
| S100 | 0 | 0 | 0 |
| S200 | 0 | 0 | 1 |
| S400 | 0 | 1 | 0 |
| S800 | 0 | 1 | 1 |
| S1600 | 1 | 0 | 0 |
| S3200 | 1 | 0 | 1 |

3.2.4.1.8.2 Heartbeat

Word 1 of the Packet Payload data area shall contain a Heartbeat of the Node generating the message. The Heartbeat shall be a 32-bit word (Unsigned Long Integer) that is initialized to zero and is incremented by one in each frame that contains new data.

The purpose of the heartbeat is to assure the applications running on the CC that the communicating Remote Node is generating fresh data. Therefore, the heartbeat shall be generated by application software, not just inserted by an independent timer.

3.2.4.1.9 Packet Trailer

Every asynchronous stream packet on the bus containing the Payload Packet Data area shall be transmitted with the Packet Trailer as the last four (4) 32-bit quadlets of the data payload. The Packet Trailer shall conform to Figure 8.

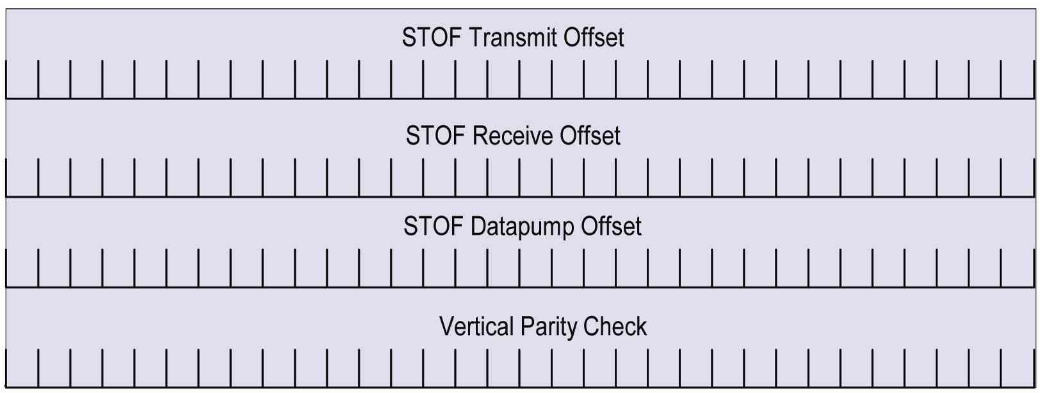


FIGURE 8 - PACKET TRAILER

3.2.4.1.9.1 STOF Transmit Offset

Word 0 of the Packet Trailer shall contain the STOF Transmit Offset (Unsigned Long Integer format). The STOF Transmit Offset shall have an accuracy of 1.0% of the STOF frame rate or 100 microseconds, whichever is greater. The resolution of the STOF Transmit Offset should be 1.0% of the accuracy value or less, as defined in the network profile slash sheet for the target application. For instance, a frame rate of 100 Hertz would require an accuracy of ±100 microseconds and a resolution of 1.0 microsecond. For CC to Remote Node messages, this will be the commanded Offset for the node, at which time it may commence transmitting. For Remote Node to CC messages, this will be the Offset the Remote Node is using.

3.2.4.1.9.2 STOF Receive Offset

Word 1 of the Packet Trailer shall contain the STOF Receive Offset (Unsigned Long Integer format). The STOF Receive Offset shall have an accuracy of 1.0% of the STOF frame rate or 100 microseconds, whichever is greater. The resolution of the STOF Receive Offset should be 1.0% of the accuracy value or less, as defined in the network profile slash sheet for the target application. For instance, a frame rate of 100 Hertz would require an accuracy of ±100 microseconds and a resolution of 1.0 microsecond. For CC to Remote Node messages, this will be the commanded Offset for the node, at which time it can expect data to be available in the FIFO of the Link Layer chip. For Remote Node to CC messages, this will be the Offset the Remote Node is using.

Messages addressed to Remote Nodes may be present on the bus at times other than the commanded Receive Offset. This would mean that not all the data on the bus might be in the appropriate offset. For this reason, out-of-sync behavior should be supported on the bus. The commanded Receive Offset is used for latency dependent operations such as loop closure, etc.

3.2.4.1.9.3 STOF Datapump Offset

Word 2 of the Packet Trailer shall contain the STOF Data Pump Offset (Unsigned Long Integer format). The STOF Data Pump Offset shall have an accuracy of 1.0% of the STOF frame rate or 100 microseconds, whichever is greater. The resolution of the STOF Data Pump Offset should be 1.0% of the accuracy value or less, as defined in the network profile slash sheet for the target application. For instance, a frame rate of 100 Hertz would require an accuracy of ±100 microseconds and a resolution of 1.0 microsecond. For CC to Remote Node messages, this will be the commanded Offset for the node, at which time it may commence transmitting. For Remote Node to CC messages, this will be the Offset the Remote Node is using.

3.2.4.1.9.4 Vertical Parity Check

Word 3 of the Packet Trailer shall be the Vertical Parity Check (VPC). The Vertical Parity Check shall be an Unsigned Long Integer. The Vertical Parity Check shall be calculated as follows:

1. Perform a Bit-wise Exclusive OR (with no carry) of every 32-bit word in the data payload of the IEEE 1394 packet excluding the Vertical Parity Check word.

2. Perform a Bit-wise Negation of the result of the Exclusive OR.

An example for calculating the VPC for an Asynchronous Stream packet follows.

1. VPC = Anonymous Subscriber Messaging Header, Message ID.

2. VPC = VPC XOR-ed with ASM Header, Security Word.

3. VPC = VPC XOR-ed with ASM Header, Node ID Word.

4. VPC = VPC XOR-ed with ASM Header, Priority/Payload Length Word.

5. VPC = VPC XOR-ed with Payload Packet Data, Health Status Word.

6. VPC = VPC XOR-ed with Payload Packet Data, Heartbeat Word.

7. Continue XOR-ing with all remaining Payload Packet Data quadlets.

8. VPC = VPC XOR-ed with Packet Trailer, STOF TX Offset.

9. VPC = VPC XOR-ed with Packet Trailer, STOF RX Offset.

10. VPC = VPC XOR-ed with Packet Trailer, STOF DP Offset.

11. VPC = VPC bit-wise negated.

3.2.4.2 Asynchronous Transactions

Asynchronous transactions may be used when a response such as acknowledge or negative acknowledge is required. An example might be software Load or integration support messages. The asynchronous packet format is shown in Figure 9.

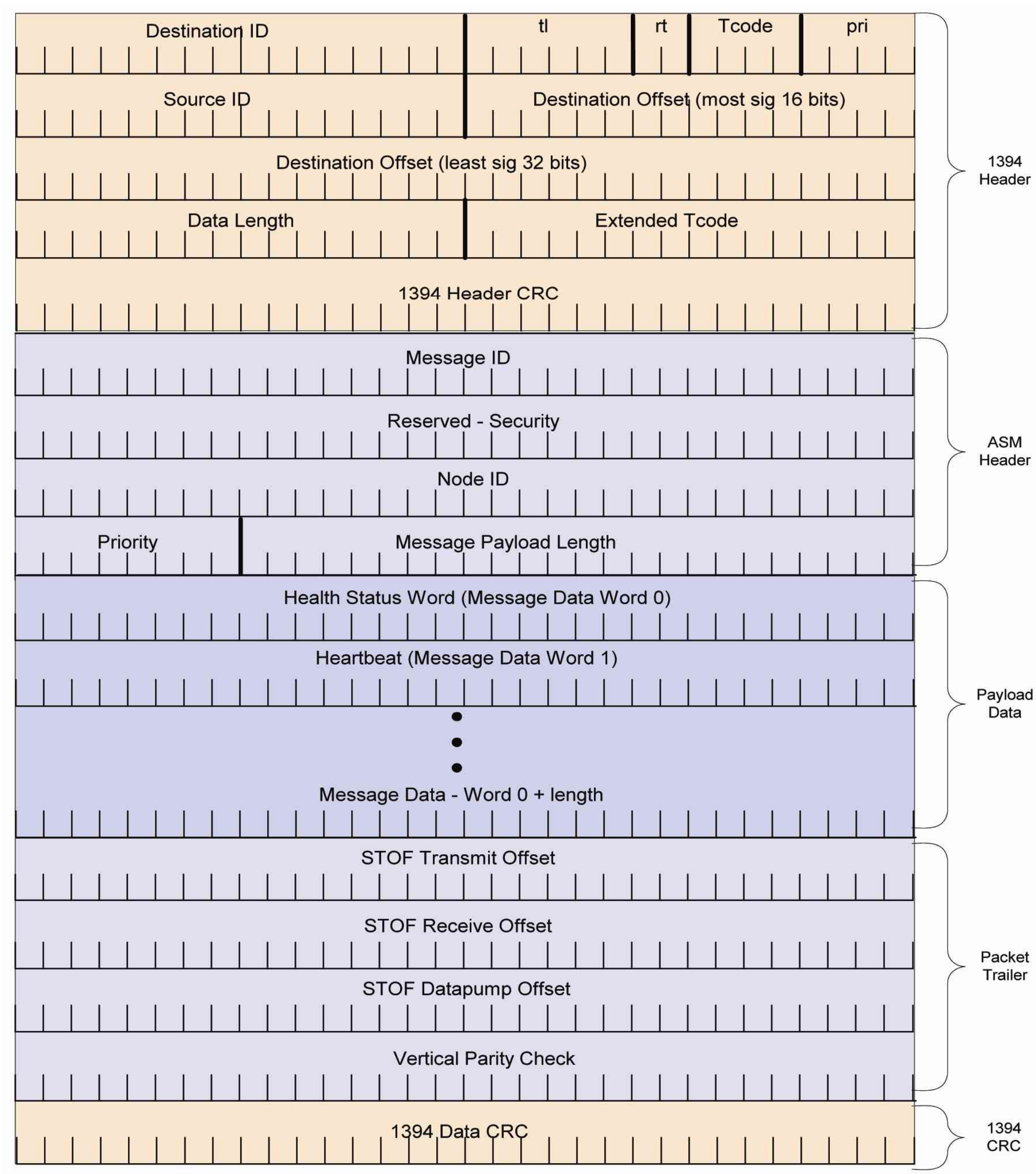


FIGURE 9 - ASYNCHRONOUS TRANSACTION PACKET

3.2.4.2.1 Destination ID

The Destination ID field shall be the Node ID of the receiving node.

3.2.4.2.2 Tl

A label specified by the requestor that identifies this transaction. The Tl field shall be a unique transaction label to identify the particular transaction to which the write request subaction belongs. This value is returned in the response packet.

3.2.4.2.3 Rt

The Rt field shall be set to indicate the required retry method as defined in the network profile slash sheet for the target application.

3.2.4.2.4 Tcode

The Tcode field shall be set to the appropriate value to identify the transaction type as defined in the IEEE-1394a-2000 specification.

3.2.4.2.5 Pri

The Pri field shall be set to 0.

3.2.4.2.6 Source ID

The Source ID field shall be set to the Node ID of the transmitting node.

3.2.4.2.7 Destination Offset

The least significant 32 bits of the Destination Offset field shall be set to the 32-bit memory offset that is requested to be written.

3.2.4.2.8 Data Length

The Data Length field shall specify the number of bytes in the message to be written or read. This shall be an unsigned short integer (16 bits).

3.2.4.2.9 Extended Tcode

The Extended Tcode shall be set to the value as defined in the network profile slash sheet for the target application.

3.2.4.2.10 Payload

The Payload field shall contain all data for the specific data message.

3.2.4.2.11 Header CRC/Data CRC

The Header and Data CRC fields are generated by the IEEE 1394 link layer. Refer to the IEEE 1394 specification for the CRC algorithm.

#### 3.2.4.3 Acknowledge Packet

The acknowledge packet consists of the acknowledge code and parity as illustrated in Figure 10. The ack_parity is the 1's complement of the ack_code. Refer to the IEEE 1394 specification for the acknowledge codes.


FIGURE 10 - ACKNOWLEDGE PACKET

### 3.2.5 IEEE-1394b Data Bus Initialization and Configuration

IEEE-1394b Data Bus initialization is initiated under the following circumstances:

- When the power state changes at the PHY
- Node attachment
- Node detachment

Three primary procedures must be performed during initialization:

- Debounce delay initiated
- Bus Reset accomplished
- Device configuration

#### 3.2.5.1 Debounce Delay

As each Remote Node is connected or powered on, it internally generates the 350-millisecond debounce delay. Upon completion of the debounce delay, it sends the reset signal onto the bus. Because not all nodes are powered on at the same time, the initialization of the bus will continue until the final node is powered on.

#### 3.2.5.2 Bus Reset

A bus reset is initiated under the following circumstances:

- When the power state changes at the PHY
- Node attachment
- Node detachment
- PHY receives a bus reset request initiated by software
- Maximum arbitration timeout reached
- Port Suspend/Disable

When any of the above conditions is detected by a PHY, it will signal a bus reset. Bus resets result in the clearing of topology information at each port, CSR register values are affected, and some PHY register values return to default.

#### 3.2.5.3 IEEE-1394b Device Configuration

IEEE-1394b device configuration occurs locally on the bus without the intervention of a host processor. Each time a new device, or node, is attached to or removed from the bus, the entire bus is reset and reconfigured.

Three primary procedures must be performed during configuration:

- Tree identification
- Self identification
- Speed negotiation performed

#### 3.2.5.4 Speed Negotiation

During the final component of bus initialization, nodes begin sending tones to one another to negotiate maximum usable speed.

#### 3.2.5.5 Tree Identification

Following bus initialization, nodes begin the tree identification phase to identify the root node and the topology of all attached nodes. The tree identification process results in a hierarchical tree structure that should resemble Figure 3 except that loops will not be allowed and will be disconnected by the PHYs.[1]

#### 3.2.5.6 Self Identification

After the tree identify phase completes, the self-identification process commences. During this process, the configuration of the nodes begins.

The following actions are performed during self-ID:

- Physical IDs are assigned to each node
- Neighboring nodes exchange transmission speed capabilities
- The topology defined during tree identification is broadcast to all nodes

Upon completion of the bus configuration, the node with the highest numbered node ID becomes the root node. The node with the highest numbered node ID, and has its IRM contender bit set, will become the Isochronous Resource Manager if isochronous packets are utilized. The node farthest from the root node will have a node ID of zero (0). Nodes successively closer to the root will have consecutively higher node IDs.

Refer to Figure 11 for a timing diagram of the total bus initialization and configuration process.

[1] Section 3.2.5 contains excerpts from the book Firewire System Architecture, Second Edition, IEEE 1394a, Mindshare Inc., 1999, with permission of the publisher.

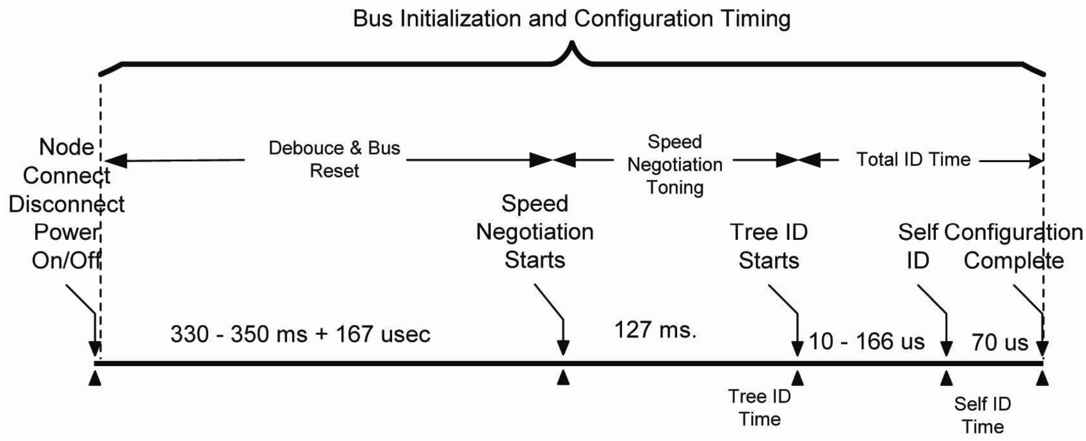


FIGURE 11 - INITIALIZATION AND CONFIGURATION TIMING

## 3.3 Node Operation

### 3.3.1 CC Node Operation

The CC Node shall be the root node, Cycle Master (if used), and Bus Manager for each respective data bus. Cycle start packets may be sent by the CC if isochronous transactions are utilized; however, they will not necessarily be synchronized to the STOF packet. For this reason, it is not acceptable to base Transmit, Receive, or Data Pump offsets on a number of cycle start packets following the STOF packet.

#### 3.3.1.1 Normal Bus Operation

Refer to Figure 16, in 3.3.2.3, for a notional picture of bus operations when utilizing asynchronous stream packets only.

##### 3.3.1.1.1 STOF Packet

The CC shall transmit a start of frame packet (STOF) at a fixed frame rate ± 0.1% of the frame rate (e.g. 10 milliseconds, 12.5 milliseconds, etc.). The STOF packet shall be an asynchronous stream packet transmitted on channel 31. The STOF message shall conform to Figure 12. Note that there is no Packet Header or Packet Trailer in a STOF packet.

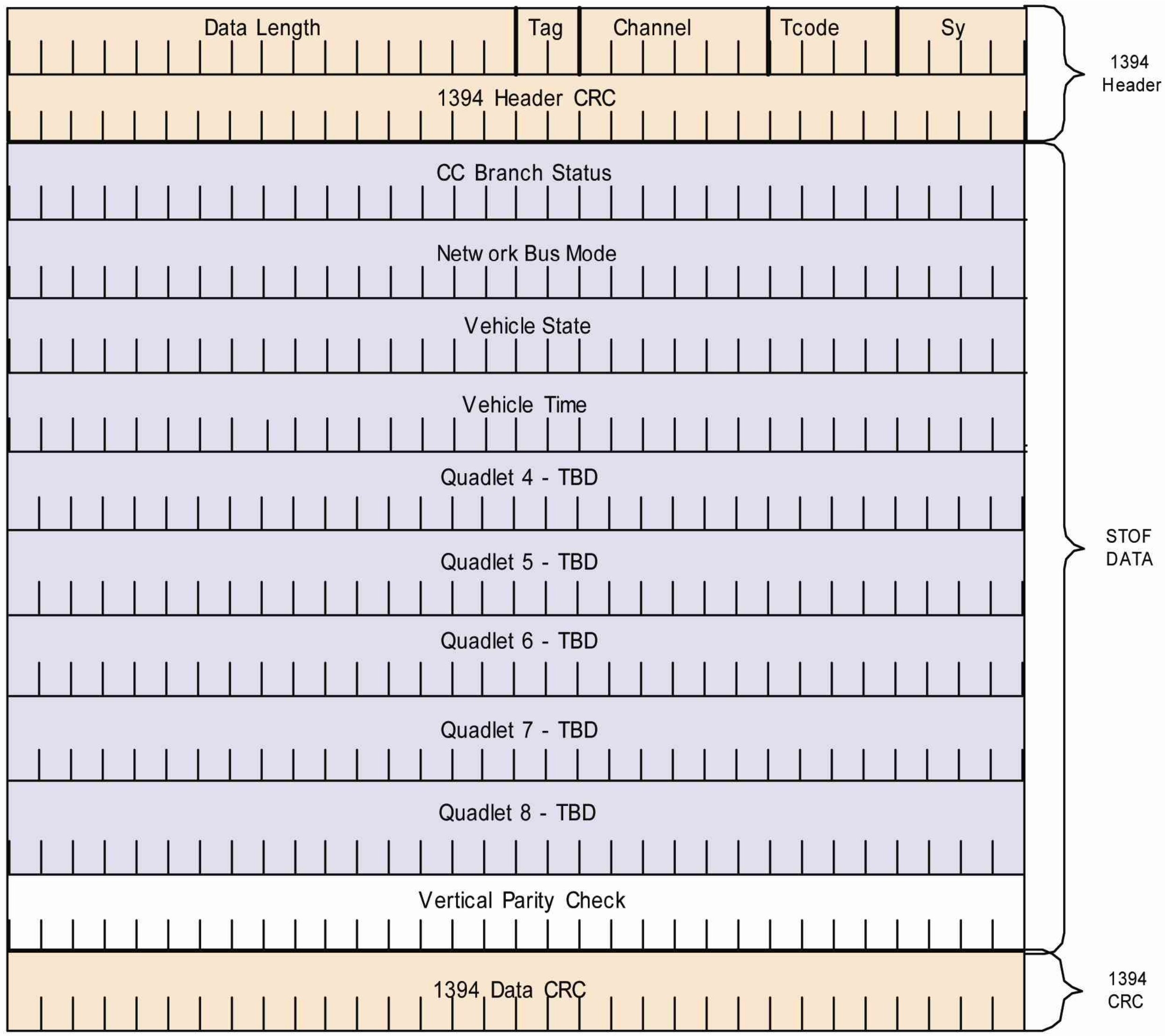


FIGURE 12 - STOF PACKET

3.3.1.1.1.1 CC Status

The CC Status Word (Long Packed Boolean) shall indicate the failure state of each of the CCs. The following is an example of assignments for a system with up to eight (8) CCs and up to sixteen (16) busses per CC. Alternate assignments should be made to accommodate different organizations as defined in the network profile slash sheet for the target application.

- LSB
- Bit 31: CC-Branch A Failure
- Bit 30: CC-Branch B Failure
- Bit 29: CC-Branch C Failure
- Bit 28: CC-Branch D Failure

- Bit 27: CC-Branch E Failure
- Bit 26: CC-Branch F Failure
- Bit 25: CC-Branch G Failure
- Bit 24: CC-Branch H Failure
- Bit 23: Connected to CC-Branch A
- Bit 22: Connected to CC-Branch B
- Bit 21: Connected to CC-Branch C
- Bit 20: Connected to CC-Branch D
- Bit 19: Connected to CC-Branch E
- Bit 18: Connected to CC-Branch F
- Bit 17: Connected to CC-Branch G
- Bit 16: Connected to CC-Branch H
- Bit 15: Connected to Bus 1
- Bit 14: Connected to Bus 2
- Bit 13: Connected to Bus 3
- Bit 12: Connected to Bus 4
- Bit 11: Connected to Bus 5
- Bit 10: Connected to Bus 6
- Bit 09: Connected to Bus 7
- Bit 08: Connected to Bus 8
- Bit 07: Connected to Bus 9
- Bit 06: Connected to Bus 10
- Bit 05: Connected to Bus 11
- Bit 04: Connected to Bus 12
- Bit 03: Connected to Bus 13
- Bit 02: Connected to Bus 14

- Bit 01: Connected to Bus 15
- Bit 00: Connected to Bus 16
- MSB

3.3.1.1.1.2 Network Bus Mode

The Network Bus Mode Word (Long Packed Boolean) shall indicate the current mode of operation for the CC Bus as defined below. One of the bits shall be set to one to indicate the current mode. These bits are mutually exclusive. If multiple bits are set, the Remote Nodes shall disregard this erroneous setting and continue to operate in the previous mode of operation. Any mode word setting other than those shown below shall be considered illegal and invalid. Use of the user defined bit assignments to accommodate different organizations should be defined in the network profile slash sheet for the target application.

Network Bus Mode Bits:

- LSB
- Bit 31: Start-up/Initialization
- Bit 30: Normal
- Bit 29: CC-In-Test (STOF messages may or may not be present depending upon which tests are being performed
- Bit 28: Reserved (Shall be initialized to zero)
- Bit 27: Program Upload
- Bit 26: In Test Mode – Read Only
- Bit 25: In Test Mode – Read/Write
- Bits 24 – 16: Reserved (Shall be initialized to zero (0))
- Bits 15 – 0: User Defined (as defined in the network profile slash sheet for the target application)
- MSB

3.3.1.1.1.2.1 Start-up/Initialization Mode Description

Upon power on or reset, the CC shall set the Start-up/Initialization bit to one, in the Network Bus Mode word of the STOF message. All other bits in the Network Bus Mode word of the STOF message shall be set to zero. Once all initialization processing is completed (as defined by in the network profile slash sheet for the target application), the Start-up/Initialization bit shall be cleared to zero.

3.3.1.1.1.2.2 Normal Mode Description

Once normal processing is ready to commence (as defined in the network profile slash sheet for the target application), the CC shall set the Normal Mode bit to one in the Network Bus Mode word of the STOF message. All other bits in the Network Bus Mode word of the STOF message shall be set to zero. Once in Normal Mode, the STOF rules will be observed and normal bus traffic will commence. When the network is not in normal mode, the Normal Mode bit shall be cleared to zero.

3.3.1.1.1.2.3 CC-In-Test Mode Description

When the CC is in test mode (as defined by in the network profile slash sheet for the target application), the CC shall set the CC-In-Test Mode bit to one in the Network Bus Mode word of the STOF message. All other bits in the Network Bus Mode word of the STOF message shall be set to zero. Network bus communication may be interrupted (STOF and receive messages may be terminated) at various times while the CC performs internal tests. The Remote Node will react to this information as determined by the particular system (e.g. perform self tests). Once test mode is completed, the CC-In-Test Mode bit shall be cleared to zero.

3.3.1.1.1.2.4 Program Upload Mode Description

When software program loading is in progress over the network (as defined in the network profile slash sheet for the target application), the CC shall set the Program Upload Mode bit to one in the Network Bus Mode word of the STOF message. All other bits in the Network Bus Mode word of the STOF message shall be set to zero. Network bus communication may be interrupted (STOF and receive messages may be terminated) at various times while the program loading is performed. Once program loading is completed, the Program Upload Mode bit shall be cleared to zero.

3.3.1.1.1.2.5 Test Mode Description (Optional)

Test Mode is another example mode to be announced by the STOF. This mode provides a common test method for all Remote Node equipment on the Network to enable memory read and/or write test operations. This relates to the STOF message and Network Bus Mode bits 25 (Read/Write Mode) and 26 (Read Only Mode). If the Read/Write bit is true, Remote Node memory values can be read or written. If the Read Only bit is true, only reading Remote Node memory data is allowed. Only RAM memory shall be allowed to be written. All non-volatile memory (Flash, EEROM, etc.) shall not be permitted to be written. All memory types may be read.

Test Mode will be enabled only if all predetermined safety interlocks are satisfied by the CCs. This mode is intended to be used during test and integration development for memory inspection (individual memory locations/parameters or ranges of memory) and memory write capabilities.

While Test Mode is active, all normal bus traffic and communication shall continue. The only difference in Normal Mode and Test Mode is the addition of test messages.

The test equipment shall be assigned a network bus channel number.

Three (3) separate messages types will be used while in Test Mode; a memory read command, a memory write command, and a response to the memory read or write command. It is recommended but not required to conform to a common test messaging format and method to support multiple Remote Node testing via the test equipment. Refer to the recommended message format and definitions in the following sections.

All test messages are communicated during the Data Pump Offset time allocation after the Remote Node completes transmitting its Data Pump message(s) (if the Remote Node is implementing any data pump message(s)). Test messages shall be transmitted by the Remote Nodes during the Data Pump Offset time and also, received by the Remote Nodes during the Data Pump Offset time. The Data Pump time allocation will be sized to accommodate the worst-case data pump message size and test message sizes for a particular system.

Upon receipt of a read or write memory command, the Remote Node should respond within two (2) frames or the number of frames as defined in the network profile slash sheet for the target application. If the command was a memory read command, the Remote Node shall continue to read and send the contents of the memory location(s), at its assigned Data Pump Offset time (after any normal Data Pump messages have been transmitted), until another memory read command is received or until power is cycled or a system-wide reset is generated.

Once Test Mode has been initiated, it cannot be exited except by cycling power or system-wide reset. This ensures that any RAM locations that have been changed will be restored to the correct values.

Figure 14 defines the packets as seen on the bus for a Read Command and Figure 15 defines the packet as seen on the bus for a Write Command. Figure 13 defines the contents of the Control Word in the packet. Note that there is no Packet Header, Heartbeat, Health Status Word, of Packet Trailer required in these packets. The data area of these packets is user definable and Figure 14 and Figure 15 illustrate one possible implementation.

3.3.1.1.1.2.5.1 Test Mode Command Word

The Command Word defines the transfer type as a Memory Read Command, a Memory Write Command, a Response to a Memory Read or Memory Write Command, or a user-defined command. The Num_Quads field defines the number of quadlets (32-bit words) to read or the number of quadlets to write in each set. The Num_Sets defines the number of different starting addresses for write or read commands. The User Defined field may be used when a transfer type greater than three (3) is requested.

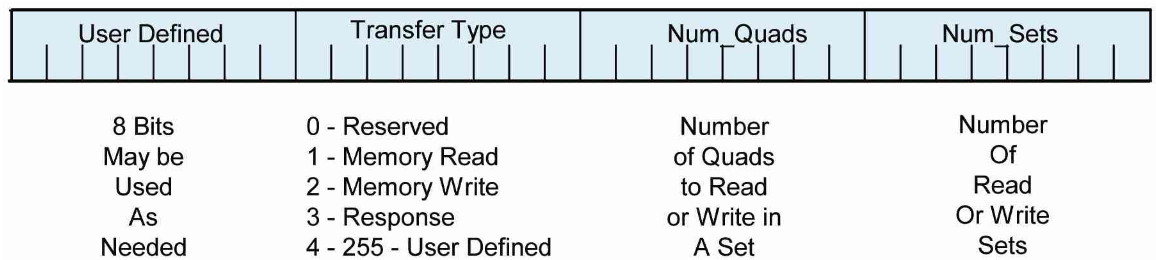


FIGURE 13 - TEST MODE COMMAND WORD

3.3.1.1.1.2.5.2 Test Mode Memory Read Command

The Test Mode Memory Read Command provides the ability to continuously read selected memory addresses. The Memory Read Addresses specify addresses at which to read memory. The Num_Quads specifies how many 32-bit quadlets to read at each address and should be set to one (1). The Num_Sets specifies how many different addresses are requested in the command packet.

The read response packet shall have a transfer type of Response (3), and echo the Num_Quads and Num_Sets fields that were present in the Read command. In the Memory Read Address fields, the data read from the memory at each respective address should be entered.

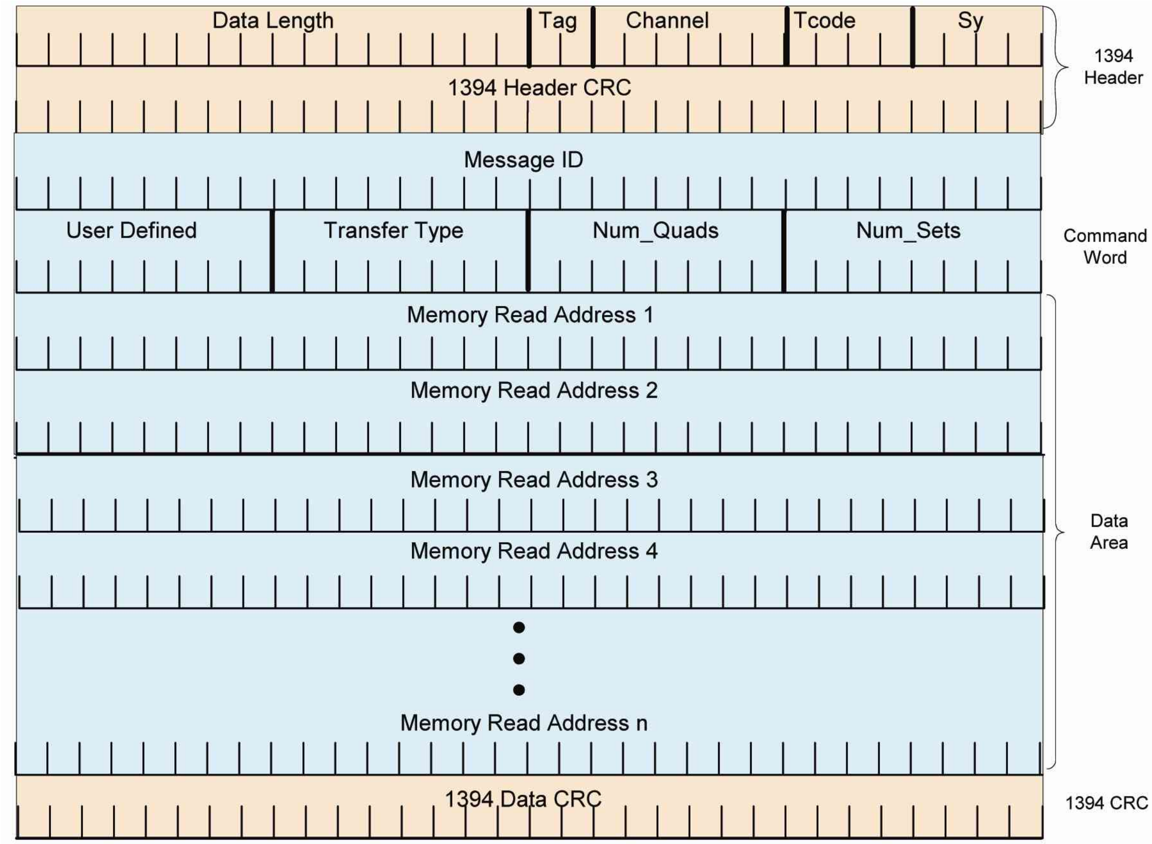


FIGURE 14 - TEST MODE READ COMMAND

3.3.1.1.1.2.5.3 Test Mode Memory Write Command

The Test Mode Memory Write Command provides the ability to write to selected memory locations in RAM memory. The Transfer Type should be set to Memory Write (2), the Num_Quads field specifies how many sequential 32-bit writes to perform at each Memory Write Starting Address, and the Num_Sets specifies how many Memory Write Starting Addresses are requested.

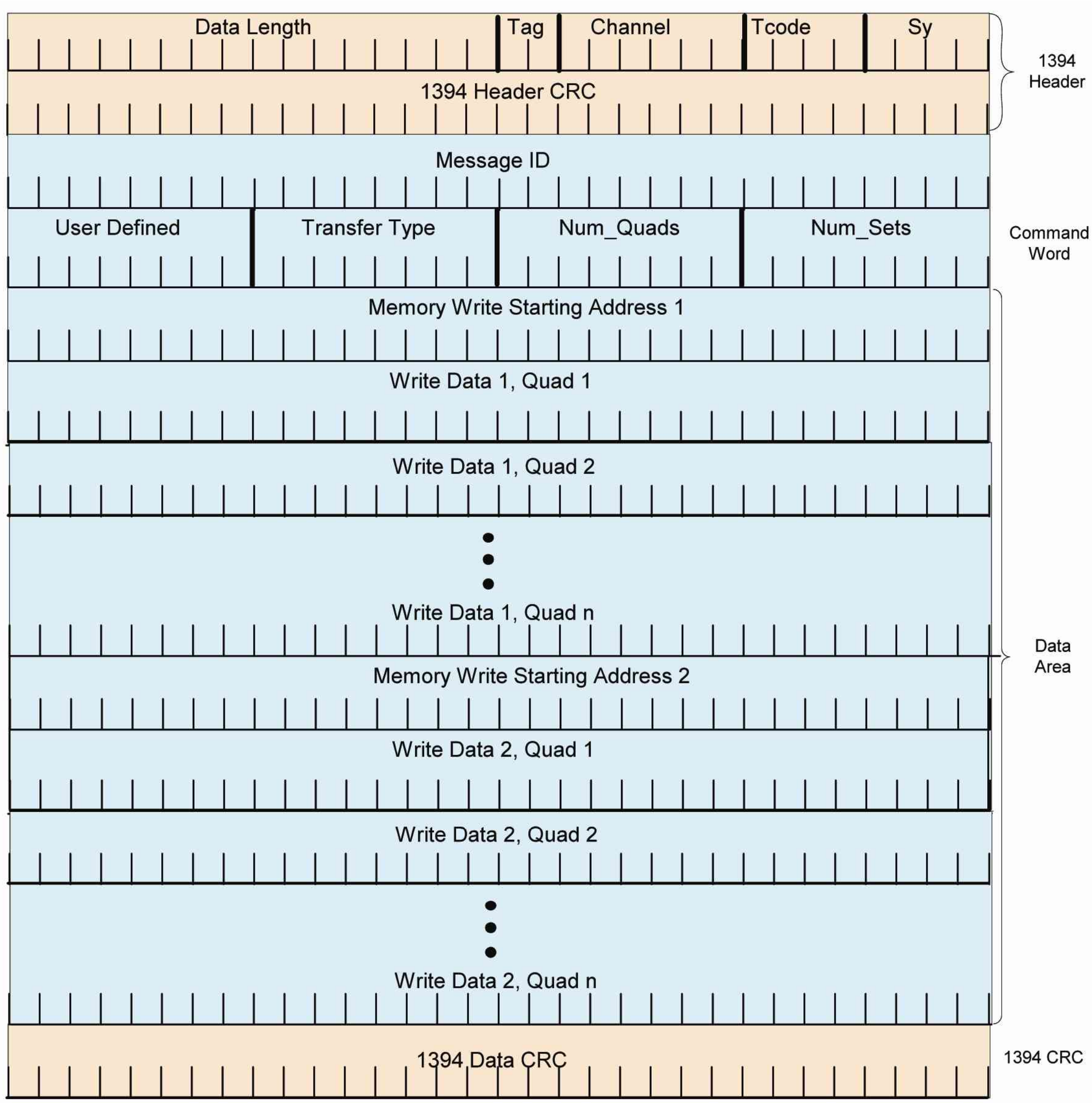


FIGURE 15 - TEST MODE WRITE COMMAND

3.3.1.1.1.3 Vehicle State

The Vehicle State Word (Long Packed Boolean) in the STOF message is used to indicate the current state of the vehicle as defined in the network profile slash sheet for the target application. Various state information can be disseminated. The below provides an example as might be used for an aircraft. The bits are set to one to indicate the current state. Current state information:

- (LSB) Bit 31: External power applied
- Bit 30: Battery power applied
- Bit 29: Internal power applied
- Bit 28: Brakes applied

- Bit 27: Engine running
- Bit 26: Cockpit canopy open
- Bit 25: Cargo door open
- Bit 24: Tailgate open
- Bit 23: In Air – Logic ‘1’ = TRUE
- Bit 22: On Ground, Not Stationary – Logic ‘1’ = TRUE
- Bit 21: On Ground, Stationary – Logic ‘1’ = TRUE
- (MSB) Bits 20-00: Spare (Shall be initialized to zero (0)

3.3.1.1.1.4 Vehicle Time

The Vehicle Time shall be a 32-bit Unsigned Long Integer denoting time as determined by the supported system. Format and use of Vehicle Time shall be defined in the network profile slash sheet for the target application.

3.3.1.1.1.5 Vertical Parity Check

The Vertical Parity Check shall be as defined in 3.2.4.1.9.4.

3.3.1.2 Message Integrity Management

The CC shall monitor the inputs from the Remote Nodes to verify proper IEEE-1394 bus operation and to verify that the Remote Node that produced the message is operating correctly. A data message shall be considered valid if all of the following conditions are met:

- The heartbeat in the Network Bus Payload Data Area has incremented since the last received message
- The data validity indicators (e.g. Vertical Parity Check) are correct
- The 1394 CRC is valid

3.3.1.3 Initialization

The CC shall set the contender bit, bit 1 in each PHY’s Register 0100b of the PHY’s Non-Paged Base Register 0, to ensure that it becomes Bus Manager (BM) and Isochronous Resource Manager (IRM) (if used). Because channel numbers and timing offsets are defined by system design, the CC will not be required to implement the IRM functions.

The CC shall set the root-holdoff bit, bit 0 in each PHY’s Register 0001b of the PHY’s Non-Paged Base Register 1, to ensure that it becomes the root node and cycle master (if used).

The CC shall commence bus operation by transmitting the STOF messages.

The CC shall update the default STOF offsets, if necessary, in the first valid message, after the STOF message, sent to a Remote Node.

The CC shall change the Network Bus Mode in the STOF message to Normal or Start-Up/Initialization after system power up, in a time as defined in the network profile slash sheet for the target application.

### 3.3.2 Remote Node Operation

#### 3.3.2.1 Required Node Hardware

Each node shall incorporate a 1394b Physical Layer Controller. Each node may incorporate either a 1394a or 1394b Link Layer Controller.

Each Remote Node should make all ports of each node available through an external connector. Connections from ports on different buses should not be mixed in a single connector since this constitutes a single-point failure.

#### 3.3.2.2 Configuration ROM (optional)

Each Remote Node may implement the Configuration ROM. Configuration ROMs may be implemented in hardware or in software (for instance, stored in the software, etc. or in a separate NV memory such as ROM, EPROM, EEPROM, etc.). It is recommended that any system that plans to utilize simple asynchronous transactions also include a minimal Configuration ROM.

#### 3.3.2.3 Normal Bus Operation

Remote Nodes shall not set their contender or root-holdoff bits (RHB) to contend for Isochronous Resource Manager, Bus Master, Root Node, or Cycle Manager.

Each Remote Node shall listen to a minimum of two channels. The two channels are to be used for the STOF channel, Channel 31 in this example, although any channel may be used, and a channel that is specific to that node by system design.

Following bus initialization and configuration as described in 3.2.5, each Remote Node shall wait for the STOF message to be sent by the CC. The Remote Node shall check the first valid message received from the CC, after the STOF message, to determine its new STOF Offsets, if necessary.

Via system design, each Remote Node shall be assigned a time relative to the STOF when it is to transmit data to the CC (STOF Transmit Offset), ±0.5% of the STOF frame rate as required by system implementation. Nodes that are connected to multiple CC branches will select a STOF using a buyer-approved algorithm that will be defined by the supplier. Each Remote Node shall be capable of reconfiguring its time to transmit, only once, at each power up/initialization. Each Remote Node shall be capable of transmitting data to the CC a system implementation dependent time after the STOF message. If a node has multiple messages to send, including messages to other Remote Nodes, those messages shall be sent back-to-back, based on the STOF Transmit Offset. Messages to the CC shall be transmitted first, followed, back-to-back, by any messages addressed to other nodes. All messages shall be transmitted within the STOF Transmit Offset time allocation. The Remote Node shall fill the Packet Trailer words 1-3 with the STOF Offsets it is using (default or CC updated).

Via the network profile slash sheet for the particular application, each Remote Node shall be assigned a time relative to the STOF that it is to expect data from the CC (STOF Receive Offset), ±0.5% of the STOF frame rate as required by system implementation. Nodes that are connected to multiple CC branches will select a STOF using a buyer-approved algorithm that will be defined by the supplier. Each Remote Node shall be capable of reconfiguring its time to expect data from the CC, only once, at each power up/initialization. Each Remote Node shall be capable of receiving data from the CC a system implementation dependent time after the STOF message. Multiple messages sent to a Remote Node shall be received back-to-back by the Remote Node. Any latency critical data messages shall be based on the STOF Receive Offset.

Via this document, each Remote Node shall be assigned a time relative to the STOF that it may use for datapump purposes (STOF Datapump Offset), ±0.5% of the STOF frame rate as required by system implementation . Nodes that are connected to multiple CC branches will select a STOF using a buyer-approved algorithm that will be defined by the supplier. Each Remote Node shall be capable of reconfiguring its time to transmit datapump data, only once, at each power up/initialization. Each Remote Node shall be capable of transmitting datapump data a system implementation dependent time after the STOF message.

Each Remote Node will have either latency critical outputs or latency critical inputs. This definition shall be provided by system design.

Refer to Figure 16 for a notional picture of bus operations with asynchronous stream packets ONLY, shown for the case of a 100 Hz frame rate.

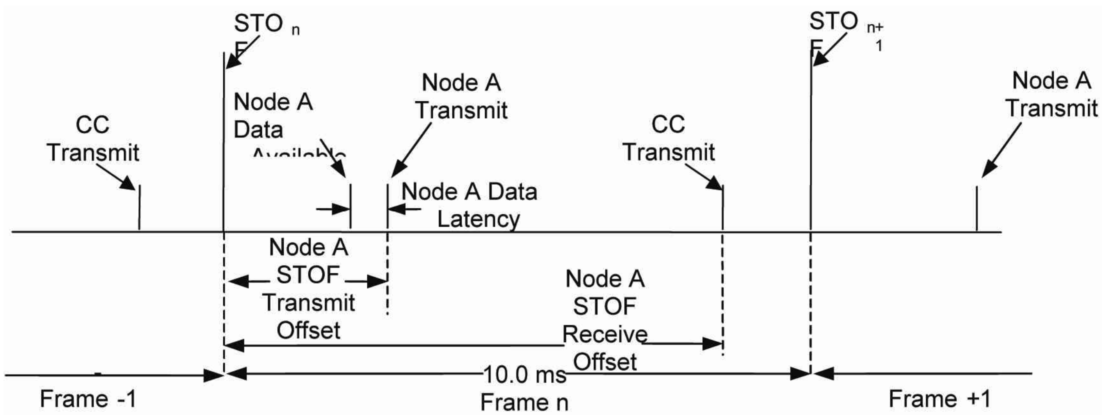


FIGURE 16 - NORMAL BUS OPERATION

3.3.2.3.1 Datapump Data Description

The one-way-only Datapump message will contain internal software parameters or memory location data to support integration and test activities. The data words would be information that isn't already contained in the normal transmit messages from the Remote Nodes. The datapump message Node Channel Assignment will be established for a particular system by system design. The data message will be transmitted on the bus defined by the STOF Datapump Offset word in the received message trailers.

3.3.2.3.2 Remote Node Start-Up/Initialization

After completing its initialization and any self-test, upon power up or reset, the Remote Node shall monitor the inputs from the CC. If the Remote Node has not detected properly timed STOF messages from the CC after a period equivalent to a defined number of frames, the Remote Node shall recognize that the CC is invalid, but shall continue monitoring the bus for valid STOF messages.

Upon receiving valid STOF messages, the Remote Node shall monitor its assigned destination channel, at its STOF Receive Offset for the first message sent to it by the CC. The first message sent to a Remote Node by the CC shall contain the STOF Offset times for transmit, receive, and datapump. These offsets may or may not differ from those assigned by system design. If any or all of these STOF Offset times differ from the assigned offsets, the Remote Node shall commence using the new offset(s) starting with the next STOF frame. If different STOF offsets are received in any successive packets, before a power up or reset has occurred, the Remote Node shall ignore them and continue using the previous offsets.

The Remote Node shall then begin normal operation and bus communication.

3.3.2.4 System Integrity Management

Each Remote Node shall monitor the inputs from the CC (including the STOF message) to determine the failure state of the CC, to verify proper 1394 bus operation, and to verify the CC software that produced the message is operating correctly.

In order for nodes to accept data from the CC during normal bus operation, all of the following conditions shall be met:

a. STOF message timing is valid if determinable by the Remote Node

b. STOF message is valid

c. STOF message indicates the CC is in a legal operating mode and is in a “good” state.

d. CC to node message is valid

In the following example, a 100 Hz frame rate is assumed.

Condition 1: A STOF message shall be considered valid if it is received 10.0 ms ± 50 μs to 150 μs from the previous STOF message, regardless of the validity (determined by conditions 1 and 2) of the previous STOF. If the STOF message does not meet the above condition for a defined number of consecutive frames, the Remote Node shall recognize the appropriate CC as failed. An exception will need to be made when the CC is in power-up/initialization or self-test mode.

Condition 2: If the STOF message timing is correct per condition 1, the node shall then check the validity of the message. A message shall be considered valid if the data validity indicator (e.g. Vertical Parity Check) is correct.

If the above condition fails, the Remote Node shall ignore the CC to Remote Node message. If the STOF message is invalid for a defined number of consecutive frames, the Remote Node shall recognize the appropriate CC as failed.

Condition 3: Once the STOF message has been determined to be valid via conditions 1 and 2, the Remote Node shall check the status of the CC. If the status indicates failed, the node shall recognize the CC as failed and ignore any messages from the CC.

If any of the preceding three (3) conditions fails, the Remote Node shall continue to transmit its data to the CC at the appropriate time (if determinable), regardless of the failure state of the CC. If the Remote Node is unable to determine its appropriate transmit time, it shall discontinue transmission.

Condition 4: If the STOF message indicates a good CC status via condition 3, the node shall then check the validity of the data message received. A data message shall be valid if all of the following conditions are met:

- The heartbeat in the ASM Message Header has incremented since the last received message

- The data validity indicators (Vertical Parity Check and Health Status Word) are correct

If either of the above conditions fails, the Remote Node shall ignore the message. The Remote Node shall continue to transmit its data to the CC at the appropriate time (if determinable), regardless of the failure state of the received message. If either of the above conditions fails for a defined number of consecutive frames, the Remote Node shall recognize the appropriate CC as failed. If the Remote Node is unable to determine its appropriate transmit time, it shall discontinue transmission.

Figure 17 provides a flowchart implementation of the System Integrity Management.

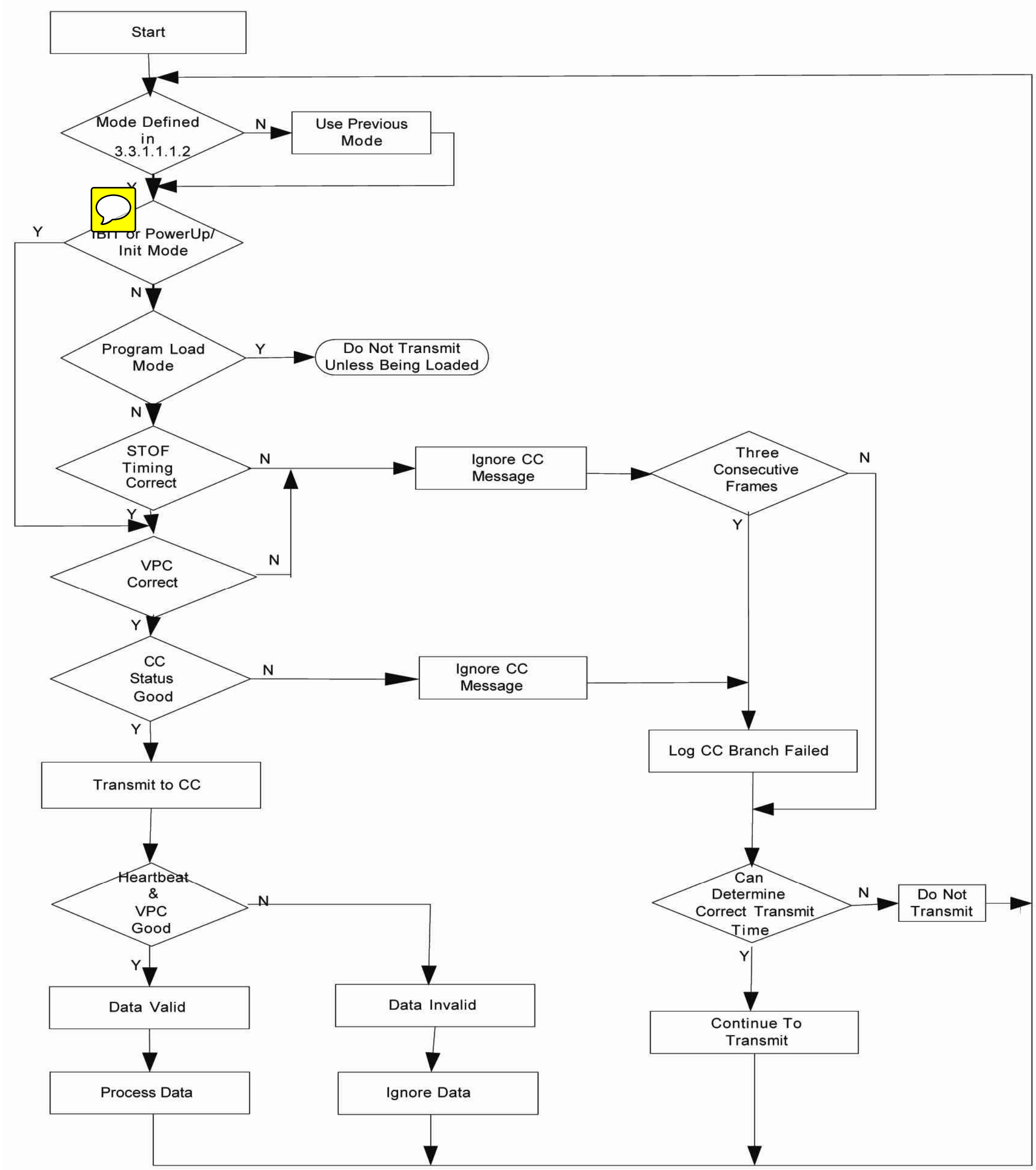


FIGURE 17 - FLOWCHART OF SYSTEM INTEGRITY MANAGEMENT

### 3.3.3 Data Packet Types

The IEEE-1394 Network shall support asynchronous streams. Asynchronous and isochronous packets are not required but may be used as needed. Typical asynchronous stream packets are illustrated in Figure 5.

#### 3.3.3.1 Asynchronous Streams

Asynchronous Streams shall occur at a specified, periodic rate. The period shall be defined based upon available bandwidth and the usage of the message. All Asynchronous Stream messages excluding the STOF and Test Mode messages shall contain the Anonymous Subscriber Messaging Header as defined in 3.2.4.1 and the Packet Trailer as defined in 3.2.4.1.9. Every Remote Node on the bus shall transmit at least one Asynchronous Stream message, per frame, so the CC can maintain connection status.

3.3.3.2 Asynchronous Transactions

Asynchronous transactions may be used for command and control, if necessary, and for messages deemed to be asynchronous in nature. Responses or returns to asynchronous transactions shall be returned following receipt of the asynchronous transaction and not at the STOF Transmit Offset time. If a receiving node detects an invalid Message ID in an asynchronous transaction, it shall return an Address Error response. Rules must be defined to ensure asynchronous packets comply with system timing constraints.

3.3.3.3 Isochronous Packets

Isochronous Packets are not required but may be used, as needed, for tasks such as streaming audio or video. Isochronous packets will use the standard IEEE-1394 packet formatting for isochronous messages, without the use of Anonymous Subscriber Message headers or Packet Trailers.

In order to preserve the integrity of the fixed frame rate methodology set out in this specification while utilizing isochronous packets, the bandwidth required (converted to time) for both asynchronous streams and isochronous packets must be explicitly allocated within the fixed frame interval such that Total Frame Time = Asynchronous Stream Time + Isochronous Time. First summing up the collective Isochronous message time within a Total Frame Time, and subtracting that amount from the Total Frame Time and allocating the remainder to asynchronous stream packets may accomplish this. This is illustrated in Figure 18.

The Total Asynchronous Stream Reserved Bandwidth shown remaining in the top half of the figure may then be 100% allocated to the Asynchronous Stream node traffic. However, when the STOF Transmit Offset Times are assigned to each node, they are spread out over the Total Frame Time interval to accommodate the interlaced isochronous data as depicted in the bottom half of Figure 18. The isochronous data packets will always be given first priority to bus access following each Cycle Start at nominal 125 microsecond intervals. But because both types of bus traffic have been explicitly allocated within the Total Frame Time, both will be able to complete all necessary transactions within each Total Frame Time.

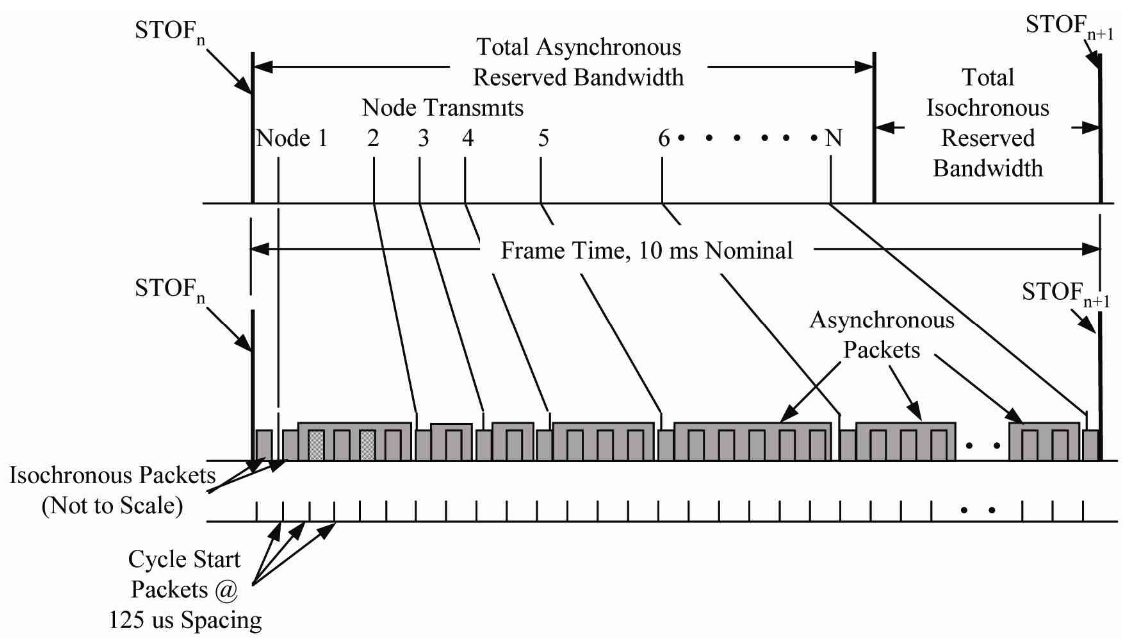


FIGURE 18 - ALLOCATING RESERVED BANDWIDTHS AND STOF TRANSMIT OFFSETS WITH MIXED DATA

Channel numbers for isochronous message transmissions shall be predefined as with asynchronous streaming packets. However, it is necessary to utilize the Cycle Master (CM) function so 125-microsecond periodic cycle starts are available to isochronous sources that expect them. It is preferred that the CC perform the Cycle Master function. It is also preferred that the IRM is not utilized due to the system determinism consideration, and bandwidth should be pre-assigned as defined in 1.4.5.

The interleaving of isochroous and asynchronous stream packet types will have the effect of creating “soft” indeterminate boundaries for the STOF times of each remote node. The extent of “softness” introduced by isochronous packet accommodation will be a function of the amount of bus bandwidth used for isochronous packets, the maximum size of isochronous packets, and the regularity and repetition rate of isochronous packet sources.

Individual systems must be designed with STOF assignments consistent with the degree of “soft” STOF offset times present, if, and as necessary.

Because of this “softness”, when latency critical asynchronous streaming is required, isochronous transmissions and the Cycle Start packets should not be utilized.

## 4. INTERFACE DEFINITIONS

Following are the node channel assignments and message description conventions.

### 4.1 Destination Node Channel Assignments

There are a total of 63 channels that can be assigned. Two channels must be assigned to the STOF and datapump messages, respectively. The remainder of the 63 channels available may be assigned to Remote Nodes, or to broadcast channels, which may be accessed by any node.

TABLE 3 - AN EXAMPLE OF REMOTE NODE CHANNEL ASSIGNMENTS

| Channel No. | Node Identifier | Bus Connected To |
|---|---|---|
| 0 | Control Computer (CC) | ALL |
| 1 | Remote Node #1 | |
| 2 | Remote Node #2 | |
| 3 | Remote Node #3 | |
| 4 | Remote Node #4 | |
| 5 | Remote Node #5 | |
| 6 | Remote Node #6 | |
| 7 | Remote Node #7 | |
| 8 | Remote Node #8 | |
| 9 | Remote Node #9 | |
| 10 | Remote Node #10 | |
| 11 | Remote Node #11 | |
| 12 | Remote Node #12 | |
| 13 | Remote Node #13 | |
| 14 | Remote Node #14 | |
| 15 | Remote Node #15 | |
| 16 | Remote Node #16 | |
| 17 | Remote Node #17 | |
| 18 | Remote Node #18 | |
| 19 | Remote Node #19 | |
| 20 | Remote Node #20 | |
| 21 | Remote Node #21 | |
| 22 | Remote Node #22 | |
| 23 | Remote Node #23 | |
| 24 | Remote Node #24 | |

| Channel No. | Node Identifier | Bus Connected To |
|---|---|---|
| 25 | Remote Node #25 | |
| 26 | Remote Node #26 | |
| 27 | Data Pump (DP) | |
| 28 | Remote Node #28 | |
| 29 | Remote Node #29 | |
| 30 | Remote Node #30 | |
| 31 | Start of Frame (STOF)* | ALL |
| 32 | Remote Node #32 | |
| 33 | Remote Node #33 | |
| 34 | Remote Node #34 | |
| 35 | Remote Node #35 | |
| 36 | Remote Node #36 | |
| 37 | Remote Node #37 | |
| 38 | Remote Node #38 | |
| 39 | Remote Node #39 | |
| 40 | Remote Node #40 | |
| 41 | Remote Node #41 | |
| 42 | Remote Node #42 | |
| 43 | Remote Node #43 | |
| 44 | Remote Node #44 | |
| 45 | Remote Node #45 | |
| 46 | Remote Node #46 | |
| 47 | Remote Node #47 | |
| 48 | Remote Node #48 | |
| 49 | Test Instrumentation (TI) | ALL |
| 50 | Remote Node #50 | |
| 51 | Remote Node #51 | |
| 52 | Remote Node #52 | |
| 53 | Remote Node #53 | |
| 54 | Remote Node #54 | |
| 55 | Remote Node #55 | |
| 56 | Remote Node #56 | |
| 57 | Remote Node #57 | |
| 58 | Remote Node #58 | |
| 59 | Remote Node #59 | |
| 60 | Remote Node #60 | |
| 61 | Remote Node #61 | |
| 62 | Remote Node #62 | |
| 63 | Broadcast Channel | ALL |

* Although the STOF is not a node on the bus, it has been shown here for informational purposes only.

# APPENDIX A - SLASH SHEET GUIDANCE

## A.1 SLASH SHEET GUIDANCE

As discussed in Section 1, this document is referred to as the “base” specification, containing the generic requirements that specify data bus characteristics, data formats and node operation. Several requirements within this document provide only example implementations and delegate the actual implementation to be specified by the network architect/integrator for a particular vehicle application. This information is to be documented in a “network profile” slash sheet, which is subservient to this base specification. In a similar manner, the electrical characteristics of the bus media, as well as connector information is to be documented in a “physical layer” slash sheet.

This appendix provides a listing of the minimum set of base specification requirements that must be further detailed by the slash sheets. In the event that a requirement is not applicable to a particular vehicle application, the respective slash sheet must state this explicitly (along with rationale) to ensure that all base specification requirements have been addressed.

## A.2 NETWORK PROFILE SLASH SHEET

The network profile slash sheet must elaborate the details of the base specification requirements listed in Table A1.

TABLE A1 - NETWORK PROFILE SLASH SHEET

| Section | Title |
|---|---|
| 3.3.1.1.1 | STOF Packet |
| 3.2.4.1.7.2 | Message ID Digits |
| 3.2.4.1.8.1 | Health Status Word |
| 3.3.1.1.1.1 | CC Status |
| 3.3.1.1.1.2 | Network Bus Mode |
| 3.3.1.1.1.2.1 | Start-up/Initialization Mode Description |
| 3.3.1.1.1.2.2 | Normal Mode Description |
| 3.3.1.1.1.2.3 | CC-In-Test Mode Description |
| 3.3.1.1.1.2.4 | Program Upload Mode Description |
| 3.3.1.1.1.3 | Vehicle State |
| 3.3.1.1.1.4 | Vehicle Time |

## A.3 PHYSICAL LAYER SLASH SHEET

The physical layer slash sheet must specify the electrical characteristics of the bus media and connector information. In addition, the physical layer slash sheet must elaborate the details of the base specification requirements listed in Table A2.

TABLE A2

| Section | Title |
|---|---|
| 3.1 | Data Bus Architecture and Operation |
| 3.2.3.1 | Transmission Bit Rate |
| 3.3.2.1 | Required Node Hardware |