



AEROSPACE STANDARD

AS1393™

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Serial Hi-Rel Ring Network for Aerospace Applications (RingNet)

RATIONALE

AS1393 has been reaffirmed to comply with the SAE Five-Year Review policy.

INTRODUCTION

Application perspective

The bandwidth and resolution of aerospace remote-sensing payloads continue to advance, placing ever increasing demands on onboard data-handling networks. At the same time, economics and rapid development requirements are driving onboard data-handling networks toward flexible, nonproprietary architectures and interface standardization. These characteristics are extensively addressed in existing ground-based networks. However, unlike most ground-based networks designed primarily to support the transfer of non-real-time data between computers, an onboard data-handling network must support the real time needs of the aerospace remote-sensing environment.

Network perspective

Aerospace remote-sensing data is characterized by synchronous components, common to continuous mode sensors, and asynchronous components, common to event driven sensors. Both sensor types have real time data-handling requirements, and sensor performance is driving data bandwidth requirements into multiple gigabit per second range. Even at these higher data rates, aerospace systems will continue to be constrained by size, weight, and power limitations. In order to achieve high data-rate performance while maintaining low size, weight, and power, onboard data-handling subsystems must employ highly integrated components and must avoid the higher layer protocol features commonly found in ground-based networks. Furthermore, space-based data-handling networks must be fault tolerant and able to withstand the rigors of launch and the harsh space environment.

Adaptation of existing ground-based network standards is not practical because of insufficient bandwidth and high power dissipation. Also, conversion of current implementations to space qualifiable processes is not feasible. Therefore, a new onboard data-handling network standard for aerospace remote-sensing applications is necessary.

Technology perspective

Fiber Optic and ASIC technologies have matured to the point that multiple gigabit data-handling networks for aerospace applications are practical. Fiber Optic technology is especially appealing because of its extremely high bandwidth capacity. Multimode fibers have been demonstrated to be radiation hard with negligible increase in signal loss over a ten year life in space radiation environments. Space qualifiable connectors have been designed and built specifically for fiber cable. Techniques for low loss termination and coupling of fibers have been perfected. High power laser diodes capable of operation over a wide temperature range and low noise optical receivers are now available. State-of-the-art semiconductor materials and processes, as well as packaging techniques, are leading towards smaller, faster, and lower power devices that will enable high-speed data-handling systems for space applications.

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1. SCOPE

This standard establishes the design requirements for a fiber optic serial interconnect protocol, topology, and media. The application target for this standard is the interconnection of multiple aerospace sensors, processing resources, bulk storage resources and communications resources onboard aerospace platforms. The standard is for subsystem interconnection, as opposed to intra-backplane connection.

1.1 Purpose

The purpose of this standard is the specification of a highly reliable and fault tolerant fiber optic network that is compatible with the harsh thermal, mechanical, and radiation environments of aerospace applications requiring small size and low power dissipation. This standard will specify a node-to-node operating data rate range of 100 Mbps through 2.5 Gbps. The standard will define physical and logical protocol, and sub-network management functions which allow mixing high-speed synchronous and asynchronous distributed access for deterministic communications.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

ANSI T1.627-1993 Telecommunications - Broadband ISDN - ATM Layer Functionality and Specification

ANSI X3.230 Fibre Channel Physical and Signaling Interface (FC-PH)

IEEE 1156.4 Environmental Specifications for Spaceborne Computer Modules, Oct. 95, D1.8

Patent No. 4,486,739 Byte Oriented DC Balanced (0,4) 8B/10B Partitioned Block Transmission Code

2.2 List of Acronyms

0x	Hexadecimal prefix
ATM	Asynchronous Transfer Mode
BCSR	BIU Configuration and Status Register
BER	Bit Error Rate
BIU	Bus Interface Unit
CCIR	CIU Command Interface Registers
CCSR	CIU Configuration and Status Register
CIU	Control Interface Unit
CRC	Cyclic Redundancy Check
DC	Direct Current
DLL	Data Link Layer

DMA	Direct Memory Access
DPRAM	Dual Post Random Access Memory
EDAC	Error Detection and Correction
FIFO	First In First Out - A FIFO is a specialized memory structure that operates such that data is written to the input port, and is read from the output port in the same order that it was written.
FWHM	Full Width Half Maximum
HEC	Header Error Check
I&T	Integration and Test
LAB	Latency Adjust Buffer
MDPL	Media Dependent Physical Layer
ML	Management Layer
NMDPL	Non-Media Dependent Physical Layer
NRZ	Non-Return to Zero
OH	Overhead
OSI	Open System Interconnection – The OSI Model describes a layered structure for communications protocol design.
Rx	Receiver (when referring to the fiber optic receivers) Received (when referring to data or Subframe OH)
SDU	Service Data Unit
SEU	Single Event Upset
SMA	Sub Miniature Assembly
TDMA	Time Division Multiple Access
Tx	Transmitter (when referring to the fiber optic transmitters) Transmitted (when referring to data or Subframe OH)
VCI	Virtual Channel Identifier
VPI	Virtual Path Identifier

2.3 Definitions

8B/10B encoding - A byte oriented encoding scheme developed by IBM which encodes 8-bit data into “DC Balanced” 10-bit symbols. 8B/10B encoding guarantees a minimum of four (4) NRZ transitions per 10-bit symbol and, with “Running Disparity”, produces a bit stream with zero dc offset.

Bandwidth reuse - A ring segmentation feature that multiplies the overall data throughput capacity of the RingNet network by allowing independent ring segments to use the same dedicated data bandwidth.



Documents

Document Sharing Hub

Bit clock - A clock recovered from the input Rx Serial Symbol stream which is bit synchronous with less than 5 degrees of single sided phase noise.

Bus Interface Unit (BIU) - Module that connects a Data Node to the RingNet bus.

Broadcast – Transmission method where one node transmits to all nodes.

Byte clock - A clock derived from the bit clock with a period equal to 10 clock cycles.

Center wavelength - The wavelength that is the arithmetic mean of the half-maximum spectral intensity points of the transmitter. If the spectral intensity distribution is symmetric and singly peaked, the center wavelength is at maximum intensity.

Control Interface Unit (CIU) - Module that connects the Control Node to the RingNet bus.

Control Node - The RingNet network management node.

Data Node - The RingNet source and destination nodes.

DC level unmodulated DC power - Average DC level of an optical signal. For example, if 100% effective power is 3 mw (4.8 dBm) and 0 % effective power is 1 mw (0 dBm) the DC Level is 2 mw (3 dBm).

Effective power - The difference, expressed in dBm between the absolute optical power measured in milliwatts at the midpoint in time of a high optical signal versus the midpoint in time of a low optical signal.

Encoded symbol - A 10-bit symbol created from 8-bit data using the 8B/10B encoding scheme.

Fiber optic receiver operating range - The range of optical power over which the fiber optic receiver will meet the specified bit error rate.

Frame - A set of consecutive time slots in which the position of each time slot can be identified by reference to a framing signal.

K28.5 - The 8B/10B control (K) symbol used as one of the RingNet Frame Sync characters.

K28.7 - The 8B/10B control (K) symbol used as the other RingNet Frame Sync character.

Latency adjust buffer - The Latency Adjust Buffer (LAB) is a FIFO function within the CIU with the ability to store one full frame of Rx Data. The LAB function insures an integral number of frames are rotating on the RingNet ring.

Multicast – Transmission method where one node transmits to several others.

Optical fall time - The time it takes for optical power to fall from 90% effective power to 10% effective power. When expressed as a percentage, the fall time is specified as a percentage of an encoded bit period.

Optical rise time - The time it takes for optical power to rise from 10% effective power to 90% effective power. When expressed as a percentage, the rise time is specified as a percentage of an encoded bit period.

SDU - The 48-byte Service Data Unit, data payload, of an ATM Cell.

Subframe OH - 12-byte RingNet Overhead structure used to transfer configuration and status information between the CIU and BIUs on the network.

Symbol - An 8B/10B encoded 10-bit symbol.

Token - The 3-bit field of authority that is passed between data Nodes using a token access method to indicate which data Node is currently in control of the medium.

Token access - The asynchronous data transmission process utilizing tokens to indicate which BIU is currently in control of a token group.

Token group - There are four token groups. Each BIU can be a member of up to four token groups. Members of each token group share access to the same Tx Data Slots defined by the Token Arbitrated Transmit Slot Masks of BCSR-(16-19). That is, BCSR-(16-19) for each member of a token group must be identical. This shared access is controlled using a simple token passing protocol.

3. NETWORK DESCRIPTION

3.1 Overview

This section introduces the RingNet functional elements, maps the relevant OSI protocol layers to the RingNet functional elements and highlights the key characteristics of the RingNet. RingNet protocol layers and processes are described in their entirety for each functional element in Sections 4 through 6.

3.1.1 Topology

The physical topology of the RingNet network is a ring of BIUs interconnected by a fiber optic Physical Plant with a CIU for network configuration and control (see Figure 3-1).

The **Physical Plant** contains the passive elements of the RingNet network; i.e., the fiber optic cables and connectors.

The **BIU**, or Bus Interface Unit, is intended to be an embedded module within each Data Node. It provides the primary data handling functions required to both send and receive data over the RingNet network.

The **CIU**, or Control Interface Unit, is intended to be an embedded module within a Control Node. It provides the primary configuration, control and status monitoring interface to the RingNet network.

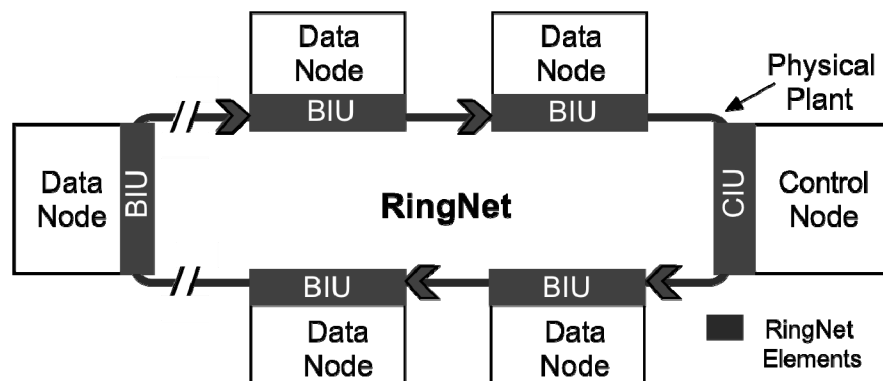


FIGURE 3-1 - RINGNET TOPOLOGY

3.1.1.1 Addressing

Address 0x7F is reserved for broadcast commands and address 0x7E is reserved for the optional Bus Monitor function, limiting the number of BIUs to 125. Address 0x00 is reserved for the CIU. The remainder of the addresses (0x01 – 0x7D) can be used for BIU addresses.

3.1.2 OSI Protocol Layer Allocation

In an effort to standardize the protocol structure, the International Standards Organization (ISO) created the 7-layer Open System Interconnection (OSI) model to define and partition the basic network processes (see Table 1). The RingNet network incorporates the three layers of this 7-layer model associated with data transfer, the Physical Layer, Data Link layer and Network Layer. The RingNet also provides a limited set of Network Management functions. These Network

Management functions have been combined with the Network Layer functions to form the RingNet Management Layer. Figure 3-2 illustrates in a simplified form the allocation of these protocol layers to the RingNet functional element.

Network Independent Layers	7 - Application Layer	Management Layer
	6 - Presentation Layer	
	5 - Session Layer	
	4 - Transport Layer	
Network Dependent Layers	3 - Network Layer	
	2 - Data Link Layer	
	1 - Physical Layer 1.1 - Non-Media Dependent Physical Layer 1.2 - Media Dependent Physical Layer	

TABLE 1 - ISO/OSI MODEL

- a) Physical Layer - In the RingNet the Physical Layer is divided into two parts, the Media Dependent Physical Layer (MDPL) and the Non-Media Dependent Physical Layer (NMDPL). The passive elements of the MDPL, the network cable and connectors, are contained within the Physical Plant. The active elements of the MDPL associated with signaling and the NMDPL processes associated with symbol encoding and timing are contained within the BIU and CIU.
- b) Data Link Layer - The Data Link Layer (DLL) functions associated with data formatting, data transfer and the Data Node interface are provided by the BIU. The DLL functions associated with network synchronization and frame formatting are provided by the CIU. No Network Independent Layers are provided by the RingNet.
- c) Management Layer - In the RingNet, the Network Layer functions associated with network bandwidth allocations and data routing, are considered part of the Management Layer. These non-real time Management Layer functions are provided by the Control Node with the CIU serving as the command and status interface between the Control Node and the RingNet network.

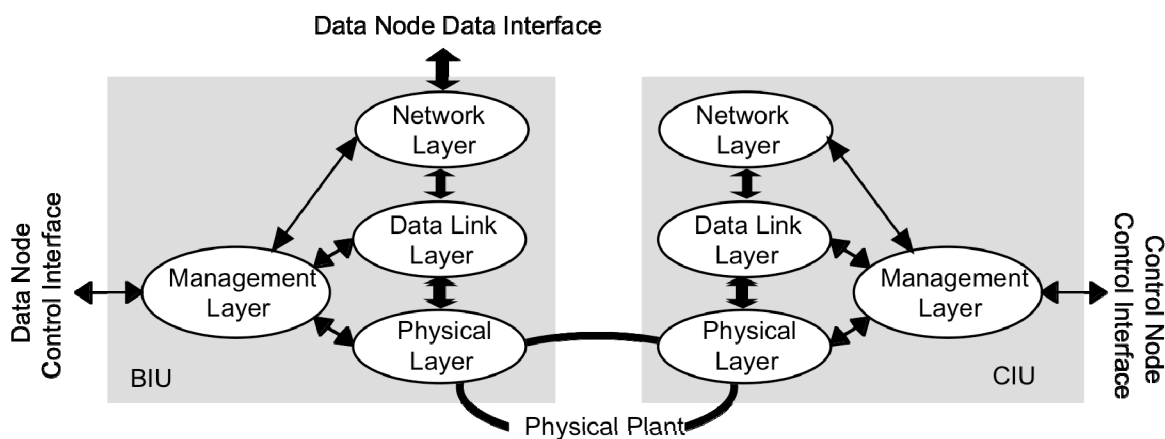


FIGURE 3-2 - PROTOCOL LAYER ALLOCATION

3.1.3 Network Characteristics

3.1.3.1 Physical Layer Characteristics

The baseline configuration for the RingNet network is a redundant, cross-strapped, serial ring with a passive optical bypass feature (see Figure 3-3). The network is capable of supporting up to 125 BIUs and a CIU with a maximum node-to-node spacing of 100 meters. Section 3.1.1.1 for explanation of the number of nodes.

The Media Dependent Physical Layer is characterized by multimode, graded index fiber with laser diode transmitters and PIN diode receivers operating at an optical frequency in the 1300 nm range. Although multi-fiber cable, multi-pin connectors and specific termini are recommended for inter-operability, the user is free to select a different cable interconnect scheme.

The Non-Media Dependent Physical Layer is characterized by a continuous transmission, serial communications mode. Data is encoded using 8B/10B symbol encoding and frame level synchronization is maintained using the unique K28.5 and K28.7 8B/10B command codes. The encoded symbols are transmitted serially using direct modulation digital On/Off signaling. The RingNet supports a selectable data rate of 100 Mbps to 2.5 Gbps.

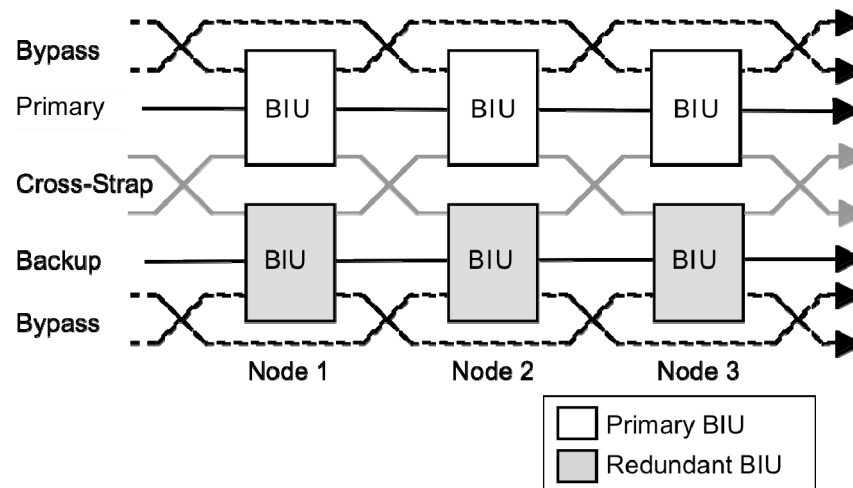


FIGURE 3-3 - RINGNET REDUNDANCY CONFIGURATION

3.1.3.2 Data Link Layer Characteristics

The Data Link Layer services are provided by the protocol processing elements of the BIU and CIU. These services include the Data Node-to-BIU and BIU-to-Data Node data transfer services, the ATM Cell formatting services, the RingNet media access services and the CIU Latency Adjust Buffer services.

Transfer of data between Data Nodes on the RingNet ring is accomplished using a simple fixed length 32-Slot, TDMA frame format. Each of the 32-Slots are a fixed 56 bytes in length and contain a standard 53-byte ATM Cell and 3 bytes of RingNet control overhead (see Figure 3-4). There is a deterministic delay around the ring equal to one, two, three or four frames depending on the number of BIUs and the distance between the BIUs in a particular network configuration. This deterministic delay is maintained by a Latency Adjust Buffer (LAB) within the CIU that compensates for BIU quantity and spacing variations and insures that an integral number of Frames is rotating on the ring.

Network bandwidth can be dedicated to a BIU using the Dedicated Transmit Slot process or shared between multiple BIUs using the Token Arbitrated process. Both processes transmit data in a broadcast mode. Data delivery can be connection oriented using the Dedicated Receive Slot process or packet oriented using the ATM Header Address process. Further explanation of these processes is provided later in this subsection.

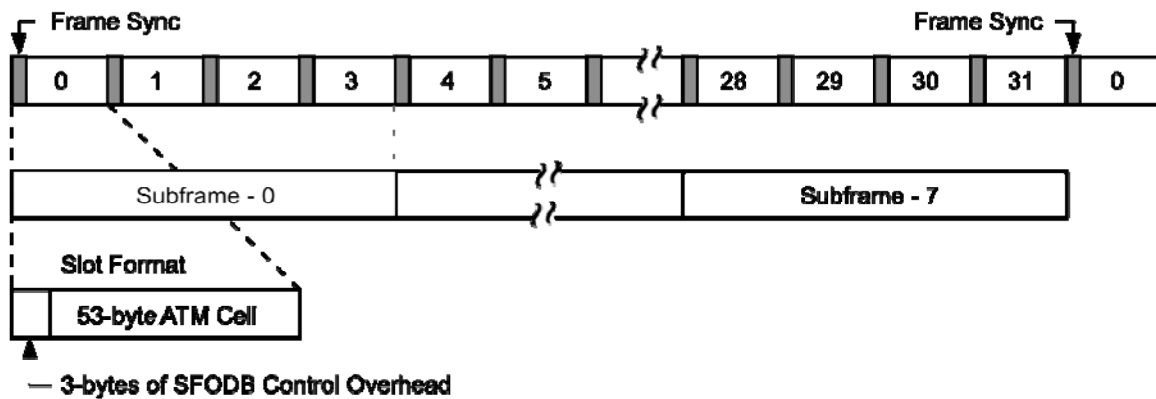


FIGURE 3-4 - RINGNET FRAME FORMAT

The transfer of an ATM Cell between the BIU and the Data Node forms the DLL boundary. The Data Node is expected to provide all message layer and higher layer OSI protocol services. In the special case of continuous unformatted data transfer between the BIU and its Data Node the BIU can perform the data segmentation and reassembly function normally attributed to the Message Layer.

The following items summarize the key characteristics of the RingNet Data Link Layer.

Data format - The RingNet network is capable of transferring continuous, unformatted data and formatted data packets between BIUs. Both data types can be transferred synchronously or asynchronously. The format of the packetized data can be either simple 48-byte blocks or fully formatted ATM Cells.

Data delivery - A RingNet network supports both circuit switched and packet switched data delivery services. These services may be mixed on the same RingNet network. Both services use multicast as the primary means of data transfer so that data destined for multiple BIUs is transmitted only once.

Data throughput - The RingNet network is scalable to allow the network to be optimized to meet specific spacecraft data throughput requirements. The network elements are scalable to accommodate a maximum node-to-node data rate of 100 Mbps to 2.5 Gbps.

Bandwidth reuse - In a structured spacecraft architecture, the data handling capacity of a RingNet network can be multiplied several times by utilizing the RingNet's Bandwidth Reuse feature. Bandwidth Reuse simply means that once data reaches the destination BIU the bandwidth used to transport that data can be immediately reused by the destination BIU or any succeeding BIU.

Deterministic latency - Another key feature of a RingNet network is the deterministic nature of the data transfer latency. The data transfer latency on a RingNet network is deterministic and stable to within one bit. This is a product of the fixed-length frame format and the Latency Adjust Buffer (LAB) within the CIU.

Data transfer options - The RingNet network offers the user several methods of transferring data between BIUs. In fact, the ability to transfer both synchronous and asynchronous data, using either dedicated or token arbitrated bus bandwidth, in either a circuit switch or packet switch network configuration, can present a confusing set of options. However, all combinations of data transfer methods available on a RingNet network can be simplified into two methods of sending data and two methods of receiving data.

Sending data - Network bandwidth is allocated by assigning one or more of the 32-Slots of a RingNet Frame to each of the BIUs. These Slots can be either dedicated to a specific BIU or shared between multiple BIUs. When Slots are dedicated, the BIU can insert data onto the network each time the assigned Slots rotate pass the BIU. When Slots are shared, the BIUs utilize token passing to arbitrate access to the assigned Slots with other BIUs. The Dedicated Transmit Slot process is primarily intended for the transmission of continuous, high rate sensor data. The Token Arbitrated process allows multiple sources to efficiently share one or more Slots on the bus. Both transmit processes

are broadcast in nature. Slot assignment is dynamically managed by the Control Node using the RingNet Subframe OH allowing real time bandwidth management without reducing data throughput.

Receiving data - The broadcast data is accepted or rejected using either a Dedicated Receive Slot process or a ATM Header Addressed process. The Dedicated Receive Slot process supports the circuit switched method of data transfer. The ATM Header Addressed process supports the packet switched method of data transfer. The latter allows a RingNet network to function in a limited capacity as a distributed ATM switch. The data acceptance criteria is based on receive masks that define the Slots to be examined and VPI/VCI addresses to be accepted. Like the transmit Slot assignments, the BIU receive masks are dynamically managed by the Control Node using the RingNet Subframe OH.

Data Node/BIU interface - Each BIU provides its Data Node with full RingNet send and receive data access through two independent interface ports. Both ports are capable of transferring data in either ATM Cell format, 48-byte format or as continuous, unformatted data. The use of the ATM Cell format as the data transfer format on a RingNet network insures compatibility with ATM ground based communications networks and ATM compatible test equipment. However, since sensor data is not normally in ATM format, the BIU send data port accepts continuous, unformatted data and builds an ATM Cell for transfer on the RingNet network. The BIU receive data port can either output data in ATM format or strip the ATM Cell header and output the data as continuous, unformatted data.

3.1.3.3 Management Layer Characteristics

The RingNet Management Layer services require the participation of both the Control Node and Data Nodes. The primary element of control resides with the Control Node. The Data Node is limited to BIU redundant element selection.

The CIU serves as the control and status interface between the Control Node and the RingNet network. The CIU provides the services required for network configuration, network synchronization and status reporting. These services are controlled and managed by the Control Node and executed by the CIU.

The RingNet Network Layer functions are considered part of the Management Layer services. Network bandwidth allocation and data routing services are established by the CIU based on configuration commands from the Control Node. In other words, the allocation of network bandwidth to specific BIUs and the data routing map that defines the transfer of data between BIUs is established by the Control Node using the BIU configuration tables. These tables are generated by the Control Node, downloaded to the CIU and distributed by the CIU to the BIUs. All network connections are established and broken using this methodology.

The following subsections provide a simplified overview of the RingNet network control services by briefly describing a power-up initialization sequence.

Redundant element selection - As spacecraft power is applied to each Control Node and Data Node the Node supplies power to one of the redundant CIU or BIU elements.

Power up & synchronization - Upon application of power the CIU automatically initiates the network synchronization sequence by the continuous transmission of a Synchronization Frame. As each BIU in the ring establishes bit and frame synchronization, the BIU allows the Synchronization Frame to pass through to the next BIU. The receipt of the Synchronization Frame by the CIU signifies that network synchronization is complete. All BIUs have established bit and frame synchronization and all BIUs are online and ready to receive configuration commands from the CIU. If synchronization is lost during normal operation, the CIU automatically initiates this process in an attempt to reestablish network synchronization.

BIU configuration - Once RingNet network synchronization is complete, the CIU sets a flags indicating to the Control Node that it is ready to accept the BIU bandwidth allocation and data routing tables. The CIU is capable of accepting these tables as individual commands from the Control Node or automatically sequencing through these commands in DMA mode.

As the CIU receives the BIU configuration tables it transfers the data to the appropriate BIU using the RingNet Subframe Overhead built into the network's 32-Slot frame. Each time a configuration command is sent to a BIU the CIU automatically polls the BIU to verify that the command was received and implemented correctly.

Normal mode - Once network initialization and the configuration of all active BIUs is completed, the CIU notifies all BIUs that data transfer may commence. During this normal data transfer mode, the CIU monitors the operation of the network & generates statistical network performance reports. While in this mode the configuration tables for any BIU can be modified. This allows the Control Node to dynamically reconfigure the RingNet network at any time.

3.2 Operation

3.2.1 Control Node Interface

This subsection defines the interface between the CIU and the Control Node. The operation of each functional interface signal listed is defined in detail in section 6.

3.2.1.1 Discrete Command and Control Interfaces

The discrete command and status interfaces listed in Table 2 allow the Control Node to select the CIU configuration, control the RingNet data rate and execute selected commands.

CIU Discrete Command & Status Interfaces	I/O	Bit Width
Bit Reference Clock	I	1
Node Tx/Rx Control	I	1
Tx Enable [2:0]	I	3
Rx Enable [2:0]	I	3
Reset	I	1
Rx Select Status [2:0]	O	3
Control Node Interrupt	O	1
CIU Fault	O	1
Control Node Interrupt (optional)	O	1

TABLE 2 - DISCRETE COMMAND AND CONTROL INTERFACE

Frequency	125 Mbps to 2.5 Gbps
Initial Stability	± 10 ppm
Temperature Stability	± 50 ppm
Harmonics and Subharmonics	- 20 dBc
Phase Noise	- 90 dBc/Hz

TABLE 3 - BIT REFERENCE CLOCK PARAMETERS

Bit Reference Clock - Used by the CIU as the Tx Bit Clock and therefore sets the symbol bit rate of the network.

Node Tx/Rx - Control Defines whether the Control Node discrete commands or the contents of CCSR-0 will control the selection of the optical transmitters and receivers.

Tx Enable [2:0] - Controls the selection of the optical transmitter, when Control Node_Node Tx/Rx Control is True. See Table 31.

Rx Enable [2:0] - Controls the selection of the optical receiver, when Control Node_Node Tx/Rx Control is True. See Table 32.

Reset - Resets the CIU internal processes and causes the CIU to initiate the network Synchronization process.

Rx Select Status [2:0] - Indicates which of the optical receivers is selected.

Control Node Interrupt - Request to the Control Node to read the contents of CCIR-(XX06-XX09) in response to the detection of an Error Frame, the detection of a BIU Poll for Status Request or a failed command execution.

In the case of an Error Frame CCIR-(XX06-XX09) will contain the Error Frame Response defined in subsection 6.3.4.3.7.

In the case of a BIU Poll for Status Request CCIR-(XX06-XX09) will contain the BIU Address and the contents of BCSR-19 from the requesting BIU.

In the case of a failed command execution CCIR-(XX06-XX09) will contain one of the Command Failed Responses defined in subsection 6.3.4.2.

CIU Fault - Indicates the CIU has loss Frame synchronization, a CCSR-parity error has been detected or one of the CIU error counters has reached its maximum value. The Control Node must poll the contents of CCSR-11 to determine the cause of the CIU Fault indication.

Control Node Interrupt (optional) - The implementation of this discrete interface signal is optional and requires the incorporation of an additional CCIR register, CCIR-XX0A. The purpose of this signal is to provide the Control Node with a single interrupt signal. It can be used in replace of Control Node Interrupt, CIU Fault and Init Failed. If implemented, this signal will represent as a request to the Control Node to read the contents of CCIR-XX0A. CCIR-XX0A will define the source of the interrupt and determine any further required action by the Control Node.

3.2.1.2 Register Interfaces

The CIU Command Interface Registers (CCIR) allows the transfer of RingNet commands and status between the Control Node and the CIU. The CIU supports two types of command execution processes, Single Command execution and Block Load Command execution. The Single Command execution process allows the Control Node to issue a command by writing into CCIR-(0-5) and status the results of the command execution by reading CCIR-(6-9). See Table 5. The Block Load Command execution process allows the Control Node to format a series of commands into a predefined block of Control Node memory and direct the CIU to execute these commands sequentially using a DMA operation. The status of the command executions are written sequentially into another predefined block of Control Node memory by the CIU. The CCIR interfaces are listed in Table 4. The set of valid CIU Commands are defined in subsection 6.3.4.2.

Control Node CCIR Interface	I/O	Bit Width
Ring Init	I	1
Read Strobe	I	1
Write Strobe	I	1
Address	I/O	16
Command/Status Word	I/O	16
Command Busy Indicator	O	1
Init Failed	O	1

TABLE 4 - CCIR INTERFACES

Ring Init - Causes the CIU to execute an Initialize Command. See 3.2.1.7.

Read Strobe - Causes the CIU to place the contents of the CCIR corresponding to the Address on the Command/Status Word.

Write Strobe - Causes the CIU to write the contents of the the Command/Status Word into the CCIR corresponding to the Address.

Address - The address (CCIR number 0 through 9) of the CCIR when the Control Node initiates the register access. The address pointer to a Control Node memory location when the CIU is executing a Block Load Command in DMA mode.

Command/Status Word - The contents of the CCIR corresponding to the Address when the Control Node is executing a CCIR Read operation. A command word from the Control Node when the Control Node is executing a Single Command or the CIU is executing a Block Load Command or an Initialize Command. A command response word from the CIU when the CIU is writing into a Control Node memory location during a Block Load Command execution.

Command Busy Indicator - Indicates to the Control Node that the CIU is in the process of executing a command.

Init Failed - Indicates the Initialize Command sequence has failed. The Control Node can either poll the contents of CCIR-XX06 through CCIR-XX09 or read the last set of entries in the Control Node memory block allocated to Configuration Command Results to determine the cause of the Init Failed indication.

3.2.1.3 CCIR Structure and Definition

A set of eleven (11), 16-bit, CIU Command Interface Registers (CCIRs) are used by the Control Node to issue configuration commands and status the command execution results. Since there are only eleven (11) CCIRs, the CIU uses the least significant byte of the CCIR Address to address the registers, the most significant byte is ignored. The "XX" in the CCIR Addresses represents a "Don't Care" for the most significant byte of the address. The content and use of each CCIR is defined as follows:

CCIR structure																	
CCIR Address (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
XX00	Command																Command Registers
XX01	0	CIU/BIU Address						0	CCSR/BCSR-Address				0	0			
XX02	Command Data Word – 1																
XX03	Command Data Word – 2																
XX04	DMA Starting Address																
XX05	DMA Ending Address																
XX06	Command Response ID Word																Command Response Registers
XX07	0	CIU/BIU Address						0	CCSR/BCSR-Address				0	0			
XX08	Polled Data Word – 1																
XX09	Polled Data Word – 2																
XX0A	Interrupt Register (optional)																

TABLE 5 - CCIR STRUCTURE

CCIR-XX00 – Command - Used to store the command word that selects the command or status operations to be performed by the CIU.

CCIR-XX01 - CIU/BIU Address & CCSR/BCSR-Address - Used to store the CIU/BIU Address and CCSR/BCSR-Address, if the command is a Load or Poll Command. If the command is not a Load or Poll command, the contents of the register is set to all zeros.

CCIR-XX02 - Configuration Data Word 1 - Stores the most significant 16-bits of the CCSR/BCSR-configuration word, if the command is a Load Command.

CCIR-XX03 - Configuration Data Word 2 - Stores the least significant 16-bits of the CCSR/BCSR-configuration word, if the command is a Load Command.

NOTE: A write operation to this register shall initiate the CIU command execution process.

CCIR-XX04 - DMA Starting Address - Contains the starting address of a command block in Control Node memory. The most significant bit of this 16-bit data field shall be set to “0” and the 2-least significant bits of the 16-bit data field shall be set to “00”.

The CIU command execution process uses the most significant bit to select between the two Control Node memory blocks allocated to Configuration Commands and Configuration Command Responses. The 2-least significant bits are used internally by the CIU to sequence through the four command words required for each CCSR/BCSR-load and poll operation.

CCIR-XX05 - DMA Ending Address - Contains the last address of the command block in Control Node memory. The most significant bit of this 16-bit data field shall be set to “0” and the 2-least significant bits of the 16-bit data field shall be set to “11” for the same reasons stated above for the DMA Starting Address.

CCIR-XX06 - Command Response ID Word - The Command Response ID Word register is used by the CIU to report the status of the last executed command to the Control Node.

CCIR-XX07 - CIU/BIU Address & CCSR/BCSR-Address - The CIU writes the polled CIU/BIU Address and CCSR/BCSR-Address into this register.

CCIR-XX08 - Polled Data Word 1 - The CIU writes the most significant 16-bits of data from the polled CCSR/BCSR-into this register.

CCIR-XX09 - Polled Data Word 2 - The CIU writes the least significant 16-bits of data from the polled CCSR/BCSR-into this register.

NOTE: The CIU notifies the Control Node when the contents of the CCIR-(XX06-XX09) are valid by setting the ML_Control Node Interface Process_Command Busy Indicator to False.

CCIR-XX0A - Interrupt Register (optional) - The implementation of this register is optional. If this register is implemented, it requires the implementation of the discrete ML_Control Node Interface Mgt_Control Node Interrupt which will be set to TRUE each time the CIU writes to the register and will be set to FALSE each time the Control Node reads this register. See Table 6.

Interrupt Register Field Definitions															
2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
Reserved															
CCSR-Parity Error = FALSE									0						
CCSR-Parity Error = TRUE									1						
Init Failed = FALSE									0						
Init Failed = TRUE									1						
CIU Sync Loss = FALSE										0					
CIU Sync Loss = TRUE										1					
Error Counter Max = FALSE											0				
Error Counter Max = TRUE											1				
BIU Poll Requested - FALSE												0			
BIU Poll Requested = TRUE												1			
Frame Type = SYNCRONIZATION[FALSE]													0		
Frame Type = SYNCRONIZATION [TRUE]													1		
Frame Type = ERROR [FALSE]														0	
Frame Type = ERROR [TRUE]														1	

TABLE 6 - INTERRUPT REGISTER FIELD DEFINITIONS

Bit 2⁶ CCSR-Parity Error indicator. Indicates that a parity error has been detected in one of the CCSR's. Bits 31–27 of the CIU Status Register, CCSR-11, will contain the address of the CCSR-register that caused the parity error.

Bit 2⁵ Init Failed indicator. Indicates that a Command Execution has failed during the Initialization Command sequence. The Control Node should either poll the contents of CCIR-XX06 through CCIR-XX09 or read the last set of entries in the Control Node memory block allocated to Configuration Command Results to determine which command failed to execute.

Bit 2⁴ CIU Sync Loss indicator. Indicates that the CIU has lost Frame Sync and has set the Frame Type to SYNCHRONIZATION in an attempt to reestablish ring synchronization.

Bit 2³ Error Counter Max indicator. Indicates that one of the CIU Error Counters has reached its maximum value. The Control Node should issue a Poll Command to CCSR-11 to determine which of the Error Counters is at its maximum value.

Bit 2² BIU Poll Requested indicator. Indicates that a BIU has set the Rx Subframe_Poll for Status Indicator field to TRUE requesting the CIU poll the BIU's Status Register. The CIU will automatically poll the BIU Status Register and place results in CCIR-(XX06-XX09).

Bit 2¹ Frame Type = Synchronization indicator. Indicates that the CIU is attempting to establish Frame Synchronization and is therefore incapable of executing configuration commands.

Bit 2⁰ Frame Type = Error indicator. Indicates that the CIU has received an Error Frame Response from a BIU indicating that the BIU has lost Frame Synchronization. The Control Node should read CCIR-(XX06-XX09) to determine which BIU was the source of the Error Frame Response.

3.2.1.4 CIU Single Command Definitions

The CIU will, at a minimum, execute the following Single Commands:

Load Command - Used to Load a CIU CCSR-or a BIU BCSR-(See Table 7).

Poll Command - Used to Poll the contents of a CIU CCSR-or a BIU BCSR-(See Table 8).

The CIU will initiate a Single Command when the Control Node writes a valid Single Command into CCIR-XX00 through CCIR-XX03. A Command Busy Indicator set to True indicates to the Control Node that the CIU is executing the command.

Load command and valid responses																
CCIR Address (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
Load Command																
XX00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
XX01	0	CIU/BIU Address							0	CCSR/BCSR-Address					0	0
XX02	Command Data Word - 1															
XX03	Command Data Word - 2															
Command Successful Response																
XX06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
XX07	0	CIU/BIU Address							0	CCSR/BCSR-Address					0	0
XX08	Command Data Word - 1															
XX09	Command Data Word - 2															
Command Failed Response																
XX06	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
XX07	0	CIU/BIU Address							0	CCSR/BCSR-Address					0	0
XX08	Command Data Word - 1															
XX09	Command Data Word - 2															

TABLE 7 - LOAD COMMAND AND VALID RESPONSES

The CIU will write the results of the command execution into CCIR-XX06 through CCIR-XX09. A Command Busy Indicator set to False indicates to the Control Node that the CIU command execution is complete and the command execution results are valid.

Upon receipt of a Load or Poll Command from the Control Node,

Set the Cmd Busy Indicator to True.

Execute the Command.

Load the Command Response into CCIR-(XX06-XX09).

Set the Cmd Busy Indicator to False, notifying the Control Node that the command status information in CCIR-(XX06-XX09) is valid.

Poll command and valid responses																
CCIR Address (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
	Poll Command															
XX00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
XX01	0	CIU/BIU Address							0	CCSR/BCSR-Address				0	0	
XX02	Don't Care															
XX03	Don't Care															
Command Successful Response																
XX06	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
XX07	0	CIU/BIU Address							0	CCSR/BCSR-Address				0	0	
XX08	Polled Data Word - 1															
XX09	Polled Data Word - 2															
Command Failed Response																
XX06	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
XX07	0	CIU/BIU Address							0	CCSR/BCSR-Address				0	0	
XX08	Invalid															
XX09	Invalid															

TABLE 8 - POLL COMMAND AND VALID RESPONSES

3.2.1.5 CIU Block Command Definitions

Block Commands allow the Control Node to load a set of sequential Configuration Commands into a predefined block of Control Node memory and direct the CIU to execute these commands using a DMA process. The Configuration Command Response for each command executed during the Block Command process is written sequentially to another predefined block of Control Node memory by the CIU.

The CIU will, at a minimum, execute the following Block Commands:

- Block Load Command - Used to Load a group of CIU CCSRs and/or BIU BCSRs defined by the CCIR-XX04 Starting Address and CCIR-XX05 Ending Address pointers (See Table 9).
- Initialize Command - Used to Load all CIU CCSRs and BIU BCSRs starting with a Control Node memory address pointer of "0000" and ending with the execution of the Stop Command (See Table 10).
- Stop Command - Used to end the Initialize Command process (See Table 11).

Block Load Command																
CCIR Address s (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
XX00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
XX01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XX02	Don't Care															
XX03	Don't Care															
XX04	DMA Starting Address															
XX05	DMA Ending Address															

TABLE 9 - BLOCK LOAD COMMAND

Initialize Command																
CCIR Address s (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
XX00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
XX01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XX02	Don't Care															
XX03	Don't Care															

TABLE 10 - INITIALIZE COMMAND

Stop Command																
CCIR Address s (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
XX00	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
XX01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XX02	Don't Care															
XX03	Don't Care															

TABLE 11 - STOP COMMAND

There are three methods that the Control Node can use to initiate a Block Command process.

Method – 1 Issue a Block Load Command.

- Load a set of CCSR/BCSR-commands into a contiguous block of Control Node memory.
- Write the Starting Address of this memory block into CCIR-XX04.
- Write the Ending Address of this memory block into CCIR-XX05.
- Write a Block Load Command into CCIR-XX00 through CCIR-XX03. (See Table 9)

Method – 2 Issue an Initialize Command

- Load a set of CCSR/BCSR-commands into a contiguous block of Control Node memory starting at 0000 hex.
- Write a Stop Command (See Table 11) as the last command of this contiguous block.
- Write an Initialize Command into CCIR-XX00 through CCIR-XX03. (See Table 10).

Method – 3 Issue a Ring Init Command.

- Load a set of CCSR/BCSR-commands into a contiguous block of Control Node memory starting at address 0000 hex address.
- Write a Stop Command (See Table 11) as the last command of this contiguous block.
- Assert Control Node_Ring Init.

Once the Block Command execution process has been initiated, the CIU will sequence through each group of four command words stored in the Control Node memory block allocated to Configuration Commands and execute each command. The CIU will write the Configuration Command Responses from each Configuration Command executed during this process into the Control Node memory block allocated to Configuration Command Responses.

The CIU uses the msb of the address pointer to select between the Control Node memory block allocated to Configuration Commands and the Control Node memory block allocated to Configuration Command Responses. That is, the CIU uses an address pointer msb of “0” when reading each Configuration Command and an address pointer msb of “1” when writing the Configuration Command Responses of each command. The CIU uses the same 15 lsb’s to both read the Configuration Commands and write the Configuration Command Responses creating a one-to-one map between Configuration Commands and Configuration Command Responses within the allocated Control Node memory.

If a command fails to execute at any point during the Block Command execution process, indicated by the assertion of the ML_Cmd Execution & Status Reporting_Execute Failed, the Control Node Interface Mgt process will set the Init Failed to true and halt the process. When the Init Failed is set to true, CCIR-(XX06-XX09) contain the Command Failed Response of the command that failed to execute.

3.2.1.6 Block Load Command Execution

Upon receipt of a Block Load Command from the Control Node (See Table 9),

Set the Cmd Busy Indicator to True.

Initiate a DMA Read from the Control Node memory block allocated to

Configuration Commands starting with the DMA Starting Address in CCIR-XX04.

Write the first four (4) entries from the Control Node memory into CCIR-(XX00-XX03).

Execute the Command.

When the command execution is complete,

Transfer the contents of Status Registers CCIR-(XX06-XX09) into the Control Node memory block allocated to Configuration Command Responses using a DMA Write process.

Continue the above four (4) word command execution and status reporting processes

until the DMA Ending Address in CCIR-XX05 is reached

Or a command fails to execute.

If the a command fails to execute,

Then,

Stop the Block Load Command process.

Set the Init Failed indicator to True.

Set the Cmd Busy Indicator to False.

Else,

When the DMA Ending Address in CCIR-XX05 is reached,

Then,

Execute the last command.

Set the Cmd Busy Indicator to False.

3.2.1.7 Initialize Command & Ring Init Execution

Upon receipt of a Initialize Command from the Control Node (See Table 10)

or the Assertion of the Control Node_Ring Init discrete,

Set the Cmd Busy Indicator to True.

Initiate a DMA Read from the Control Node memory block allocated to

Configuration Commands starting with the DMA Starting Address equal to "0000 -hex".

Write the first four (4) entries from the Control Node memory into CCIR-(XX00-XX03)

and Assert the Execute Command indicator.

When the command execution is complete,

Transfer the contents of Status Registers CCIR-(XX06-XX09) into the Control Node memory block allocated to Configuration Command Responses using a DMA Write process.

Continue the above four (4) word command execution and status reporting processes

Until a Stop Command is read from the Control Node memory,

Or a command fails to execute.

If the a command fails to execute,

Then,

Stop the Block Load Command process.

Set the Init Failed indicator to True.

Set the Cmd Busy Indicator to False.

Else,

When a Stop Command is read from the Control Node memory;

Then,

Stop the Block Load Command process.

Set the Cmd Busy Indicator to False.

3.2.1.8 Error Frame Report

The CIU will notify the Control Node when an Error Frame has been received from one of the BIUs by asserting the Control Node Interrupt. The CIU/BIU Address field of CCIR-7 will contain the Address of the BIU that is generating the Error Frame. A BIU will generate an Error Frame when it is unable to acquire Frame Sync on the incoming serial symbol stream.

Error Frame Response																
CCIR Address s (hex)	2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
XX06	1	1	1	1	1	1	1	1	1	1	1	1	0	RX Status		
XX07	0	CIU/BIU Address							0	CCSR/BCSR Address				0	0	
XX08	Invalid															
XX09	Invalid															

TABLE 12 - ERROR FRAME RESPONSE

3.2.1.9 Poll For Status Report

The CIU will notify the Control Node when a BIU has requested a Poll for Status indicating a problem within the BIU or a Node Service Request by asserting the Control Node Interrupt. CCIR-(XX06-XX09) will contain a Poll command Successful Response as defined in Table 8. The CIU/BIU Address field of CCIR-7 will contain the Address of the BIU that generated the Poll for Status and CCIR-(8-9) will contain the contents of the BIU Status Register (BCSR-19).

3.2.1.10 CIU Sync Loss Notification

The CIU will notify the Control Node when the CIU has lost Frame synchronization by asserting the Control Node Interrupt. The Rx Frame Type Status field of the CIU status register, Rx Frame Type Status in CCSR-11, will indicate that the RingNet is no longer in Normal mode. See 6.3.4.4.6. The Control Node should poll all CCSR-and BCSR-configuration registers to verify the RingNet configuration , reconfigure the RingNet ring, if required; and then, set the CIU Frame Type to NORMAL by executing a Load Command to CCSR-0.

3.2.2 Data Node Interfaces

This subsection defines the control interface between the BIU and the Data Node. The operation of each functional interface signal listed is defined in detail in Section 6.

3.2.2.1 Control Interfaces

The discrete command and status interfaces listed in Table 13 allow the Data Node to set the BIU's Address, select and status the BIU Tx and Rx configuration and request a predefined service from the Control Node.

Data Node Control Interfaces	I/O	Bit Width
Node Tx/Rx Control	I	1
Tx Select [2:0]	I	3
Rx Select [2:0]	I	3
Rx Select Status [2:0]	O	3
Node Service Request	I	1
SVC_Busy	O	1
BIU Address	I	7

TABLE 13 - DATA NODE CONTROL INTERFACES

Node Tx/Rx Control

Defines whether the Data Node discrete commands or the contents of BCSR-8 will control the selection of the optical transmitters and receivers.

Tx Select[2:0]

Controls the selection of the optical transmitter, if **Data Node_Node Tx/Rx Control** is TRUE. See Table 31.

Rx Select[2:0]

Controls the selection of the optical receiver, if **Node Tx/Rx Control** is TRUE. See Table 32.

Rx Select Status[2:0]

Indicates which of the optical receivers is selected.

Node Service Request

Used by the Data Node to request any predefined service from the Control Node.

SVC Busy

This output is used in conjunction with the Node Service Request process. When the Data Node asserts the Node Service Request input to the BIU, the BIU asserts SVC_Busy. This provides a handshake between the BIU and its Data Node. SVC_Busy remains high until a response is received from the CIU to poll the BCSR-19 register.

BIU Address

Used by the Data Node to set the BIU's node Address (0-125). Each BIU in the network must have a unique BIU Address in order to communicate properly with the CIU.

3.2.2.2 Data Interfaces

Data Node Data Interfaces	I/O	Bit Width
BIU-to-Node FIFO Interfaces		
FIFO Clear	I	1
FIFO Output Data	O	32
Beginning Cell Indicator	O	1
Transfer Enable	O	1
FIFO Full	O	1
Node-to-BIU FIFO Interfaces		
FIFO Clear	I	1
FIFO Input Data	I	32
Beginning Cell Indicator	I	1
Transfer Enable	O	1
FIFO Full	O	1

TABLE 14 - DATA NODE DATA INTERFACES

BIU-to-Node FIFO Interfaces:**FIFO Clear**

Used by the Data Node to Clear the BIU-to-Node FIFO.

FIFO Output Data

The BIU-to-Node FIFO output data port. The output data format options are illustrated in Figure Figure 3-5. Output data format selection is controlled by Node-to-BIU ATM/Raw Data Select in BCSR-8.

Beginning Cell Indicator

Used by the BIU to indicate the Beginning of a 53-byte ATM Cell or 48-byte Raw Data Cell. See Figure 3-5.

Transfer Enable

Used by the BIU to control the BIU-to-Node FIFO Read access.

FIFO Full

Used by the BIU to indicate that the BIU-to-Node FIFO is full.

Node-to-BIU FIFO Interfaces

FIFO Clear

Used by the Data Node to Clear the Node-to-BIU FIFO.

FIFO Input Data

The Node-to-BIU FIFO input data port. The input data format options are illustrated in Figure 3-5. Input data format selection is controlled by Node-to-BIU ATM/Raw Data Select in BCSR-8.

Beginning Cell Indicator

Used by the Data Node to indicate the Beginning of a 53-byte ATM Cell or 48-byte Raw Data Cell. See Figure 3-5.

Transfer Enable

Used by the BIU to control the Node-to-BIU FIFO Write access.

FIFO Full

Used by the BIU to indicate that the Node-to-BIU FIFO is full.

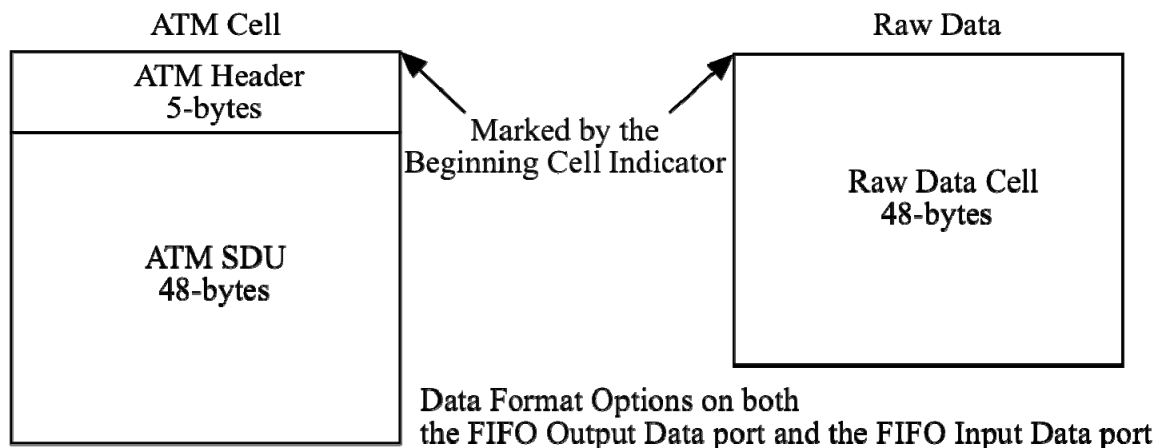


FIGURE 3-5 - DATA NODE DATA FORMAT OPTIONS

3.2.3 RingNet Frame Structure

3.2.3.1 Frame, Subframe, Slot, and Symbol Definition

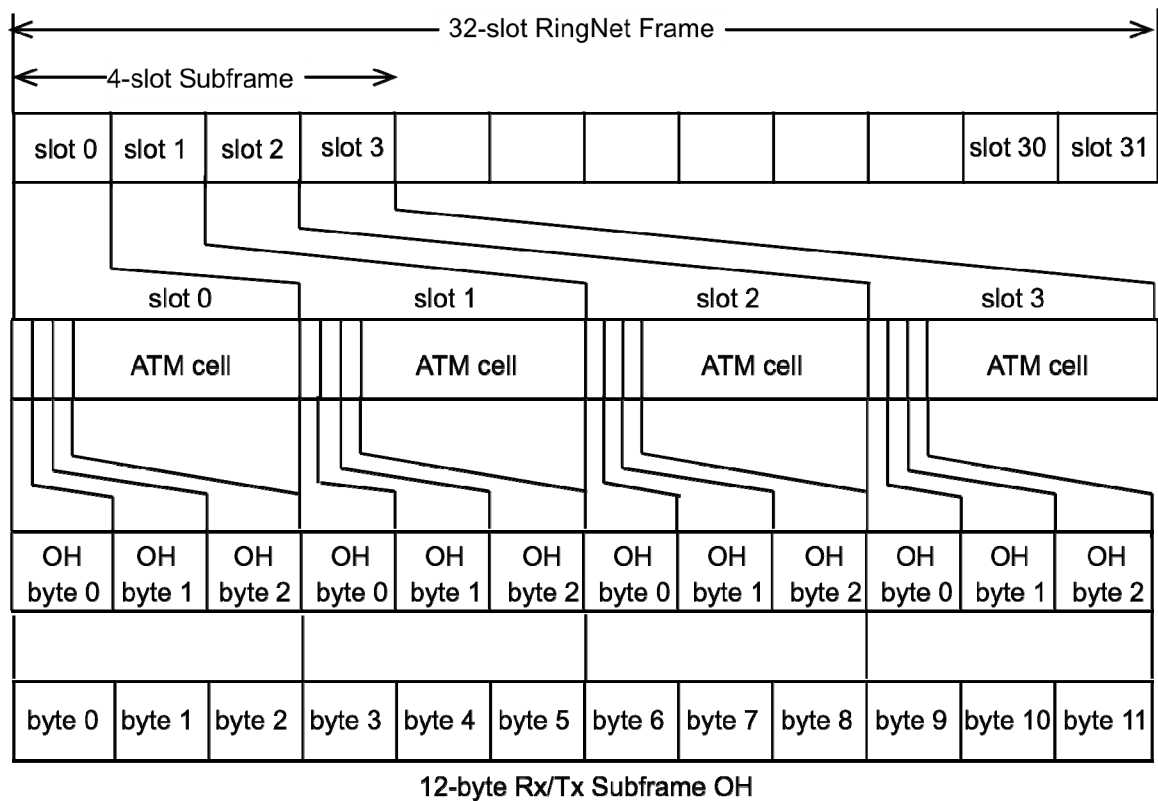


FIGURE 3-6 - SUBFRAME STRUCTURE

Figure 3-6 illustrates the RingNet Frame, Subframe and Slot structure.

Frame

A Frame is defined as 32 contiguous Slots. A Frame Sync symbol defines the beginning of each RingNet Frame.

Subframe

A Subframe is defined as 4 contiguous Slots. There are eight (8) Subframes in each Frame.

Slot

A Slot is defined as 56-symbols. Each Slot contains 3-symbols of encoded Subframe OH and a 53-symbol encoded ATM Cell.

Symbol

A Symbol is an 8B/10B encoded byte as defined in ANSI X3.230, Fibre Channel Physical and Signalling Interface (FC-PH), with Running Disparity implemented.

Frame Sync Symbol

Two 8B/10B Control Codes (K Codes) are use as Frame Sync symbols, K28.5 and K28.7. See the definition of Subframe Byte - 0 for Subframe “0”.

3.2.3.2 Subframe OH Field Definitions

The Subframe OH used to transfer Configuration and Status information between the CIU and the BIUs is a 12-byte field composed of 3 bytes of overhead from four consecutive RingNet frame Slots. See Figure 3-6 and Figure 3-7. The Rx Subframe OH and Tx Subframe OH are identical in format and content. The Rx and Tx distinguish between the Subframe OH received by the CIU/BIU and the Subframe OH transmitted by the CIU/BIU respectively. There are 8-Subframes within each 32-Slot RingNet Frame. The Overhead bytes that make up each Subframe are defined as follows:

Subframe 0	Overhead bytes from 0 to 2	From slots 0 to 3
Subframe 1	Overhead bytes from 0 to 2	From slots 4 to 7
Subframe 2	Overhead bytes from 0 to 2	From slots 8 to 11
Subframe 3	Overhead bytes from 0 to 2	From slots 12 to 15
Subframe 4	Overhead bytes from 0 to 2	From slots 16 to 19
Subframe 5	Overhead bytes from 0 to 2	From slots 20 to 23
Subframe 6	Overhead bytes from 0 to 2	From slots 24 to 27
Subframe 7	Overhead bytes from 0 to 2	From slots 28 to 31

TABLE 15 - MAPPING BETWEEN OVERHEAD BYTES AND SLOTS

See Figure 3-7 and the following field definitions for a detail definition of each Subframe OH field.

Subframe Byte - 0								Subframe Byte - 1								Subframe Byte - 2								
2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	
	2 ²	Token N (bit 2 ²)							2 ¹	Token N (bit 2 ¹)							2 ⁰	Token N (bit 2 ⁰)						
0		0	0	0										0	1									
Subframe Count					2 ²	2 ¹	2 ⁰	2 ⁰	Poll Response Indicator							2 ⁰	Poll for Status Indicator							
K28.5 or K28.7 Frame Sync for Subframe 0 only										2 ⁷	2 ⁶	2 ⁵	2 ⁴	CRC (8-bit)				2 ³	2 ²	2 ¹	2 ⁰			
																Frame Count							2 ¹	2 ⁰
Subframe Byte - 3								Subframe Byte - 4								Subframe Byte - 5								
	2 ²	Token (N+1) (bit 2 ²)							2 ¹	Token (N+1) (bit 2 ¹)							2 ⁰	Token (N+1) (bit 2 ⁰)						
S	Spare								S	S	Spare													
		2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	CIU/BIU Address (7-bits)															
												2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	CCSR/BCSR Address (5-bits)							
								Load/Poll Command							2 ⁰									
								Rx Select Status (3-bits)							2 ²	2 ¹	2 ⁰							
								Frame Type (2-bits)							2 ¹	2 ⁰								
Subframe Byte - 6								Subframe Byte - 7								Subframe Byte - 8								
	2 ²	Token (N+2) (bit 2 ²)							2 ¹	Token (N+2) (bit 2 ¹)							2 ⁰	Token (N+2) (bit 2 ⁰)						
2 ³¹	Load/Poll Data (msb)																							
		2 ³⁰	2 ²⁹	2 ²⁸	2 ²⁷	2 ²⁶	2 ²⁵	2 ²⁴	Load/Poll Data (2 ³⁰ thru 2 ²⁴)															
									2 ²³	2 ²²	2 ²¹	2 ²⁰	2 ¹⁹	2 ¹⁸	2 ¹⁷	Load/Poll Data (2 ²³ thru 2 ¹⁷)								
								Load/Poll Data (2 ¹⁶)							2 ¹⁶									
																Spare (5-bits)			S	S	S	S	S	
Subframe Byte - 9								Subframe Byte - 10								Subframe Byte - 11								
	2 ²	Token (N+2) (bit 2 ²)							2 ¹	Token (N+2) (bit 2 ¹)							2 ⁰	Token (N+2) (bit 2 ⁰)						
2 ¹⁵	Load/Poll Data (2 ¹⁵)																							
		2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	Load/Poll Data (2 ¹⁴ thru 2 ⁸)															
									2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	Load/Poll Data (2 ⁷ thru 2 ¹)								
								Load/Poll Data (2 ⁰)							2 ⁰									
																Spare (5-bits)			S	S	S	S	S	

FIGURE 3-7 - SUBFRAME STRUCTURE

Byte-0 of Subframe “0” contains the K28.5 or K28.7 Frame Start Delimiter. This unique 8B/10B command code occurs once at the start of each frame and represents Subframe Count “000”. The decoded K28.5 and K28.7 command codes maintain the integrity of the Free and Claim Token bit respectively.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
1	0	1	1	1	1	0	0	K28.5 code
1	1	1	1	1	1	0	0	K28.7 code

TABLE 16 - VALUES FOR SUBFRAME BYTE 0, SUBFRAME 0

Subframe Byte - 0 for Subframes 1 - 7

Byte-0 of Subframes “1-7” contains four static bits, the first bit of the majority vote Token field associated with the frame Slot and the Subframe Count.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0		0	0	0				Static	
	0							1st Majority Vote Token bit for Slot (N)	Free
	1								Claim
					2^2	2^1	2^0	Subframe Count	

TABLE 17 - VALUES FOR SUBFRAME BYTE 0, SUBFRAMES 0-7

Subframe Byte – 1

Byte-1 of all Subframes contains the Poll Response Indicator, the second bit of the majority vote Token field associated with the frame Slot, the 4 msb's of the CRC for the previous subframe and the two static bits.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0								Poll Response Indicator	FALSE
1									TRUE
	0							2nd Majority Vote Token bit for Slot (N)	Free
	1								Claim
		2^7	2^6	2^5	2^4			4 msb's of CRC for Subframe (N-1)	
						1	0	static	

TABLE 18 - VALUES FOR SUBFRAME BYTE 1

Subframe Byte – 2

Byte-2 of all Subframes contains the Poll for Status Indicator, the third bit of the majority vote Token field associated with the frame Slot, the 4 lsb's of the CRC for the previous subframe and the Frame Count.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
0								Poll for Status Indicator	FALSE
1									TRUE
	0							3rd Majority Vote Token bit for Slot (N)	Free
	1								Claim
		2^3	2^2	2^1	2^0			4 lsb's of CRC for Subframe (N-1)	
						2^1	2^0	Frame Count	

TABLE 19 - VALUES FOR SUBFRAME BYTE 2

Subframe Byte – 3

Byte-3 of all Subframes contains one spare bit, the first bit of the majority vote Token field associated with the frame Slot and the 6 msb's of the BIU Address.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
X								Spare	
	0							1st Majority Vote Token bit for Slot (N+1)	Free
	1								Claim
		2^6	2^5	2^4	2^3	2^2	2^1	6 msb's of the BIU Address	

TABLE 20 - VALUES FOR SUBFRAME BYTE 3

Subframe Byte – 4

Byte-4 of all Subframes contains the lsb of the BIU Address, the second bit of the majority vote Token field associated with the frame Slot and the 4 msb's of the BCSR-Address.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
2^0								lsb of the BIU Address	
	0							2nd Majority Vote Token bit for Slot (N+1)	Free
	1								Claim
		X	X					Spare	
				2^4	2^3	2^2	2^1	4 msb's of the BCSR-Address	

TABLE 21 - VALUES FOR SUBFRAME BYTE 4

Subframe Byte – 5

Byte-5 of all Subframes contains the lsb of the BCSR-Address, the third bit of the majority vote Token field associated with the frame Slot, the Load/Poll Command field, the Rx Select Status field and the Frame Type field.

2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰		
2 ⁰								lsb of the BCSR-Address	
	0							3rd Majority Vote Token bit for Slot (N+1)	Free
	1								Claim
		0						Load/Poll Command	Poll
		1							LOAD
			1	0	0			Rx Selected = PRIMARY	
			0	1	0			Rx Selected = CROSS-STRAP	
			0	0	1			Rx Selected = BYPASS	
						0	0	Frame Type = SYNCHRONIZATION	
						0	1	Frame Type = Configuration	
						1	0	Frame Type = Error	
						1	1	Frame Type = Normal	

TABLE 22 - VALUES FOR SUBFRAME BYTE 5

Subframe Byte – 6

Byte-6 of all Subframes contains Load/Poll Data and the first bit of the majority vote Token field associated with the frame Slot.

2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰		
2 ³¹		2 ³⁰	2 ²⁹	2 ²⁸	2 ²⁷	2 ²⁶	2 ²⁵	Load/Poll Data	
	0							1st Majority Vote Token bit for Slot (N+2)	Free
	1								Claim

TABLE 23 - VALUES FOR SUBFRAME BYTE 6

Subframe Byte – 7

Byte-7 of all Subframes contains Load/Poll Data and the second bit of the majority vote Token field associated with the frame Slot.

2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰		
2 ²⁴		2 ²³	2 ²²	2 ²¹	2 ²⁰	2 ¹⁹	2 ¹⁸	Load/Poll Data	
	0							2nd Majority Vote Token bit for Slot (N+2)	Free
	1								Claim

TABLE 24 - VALUES FOR SUBFRAME BYTE 7