ORIGINAL ARTICLES

Onboard Ship Optical Switch Controller Using Embedded Internet Based System for Survivability Application

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ABSTRACT

Shipboard optical network with redundant topology and the implementation of online optical switch controller using embedded internet based system for survivability data communication transfer was introduced. The online optical switch is developed using a simple microcontroller PIC18F97J60 used for online monitoring and fault identification by controlling optical switch connected to the network. The proposed system architecture is discussed considering the possible hardware and software elements to develop the online switch controller. Finally, the benefits and limitations of such system are discussed using some initial results obtained in the experimental activities.

Key words: Shipboard optical network, network survivability, online optical switching, Microcontroller.

Introduction

Onboard a ship, connection survivability of data communication throughout the networks is vital. With the growing complexity of modern warship weapon systems, automation of platform and its monitoring systems, improvement of command and control, enhancement in standard of living for crew members are the key factor for the demand of higher data transfer capabilities. Currently, the information transfer requirements were met by installation of dedicated cables interconnecting the systems using point-to-point cabling. The ship cabling technology onboard the warship is using combination of silica fiber and copper cables or most of the equipments and system is connected using only copper cables. The disadvantages of this connection are that, the information transfer is vulnerable to outages caused by cable failure or destruction of any cable. Back-up paths may leads to massive cabling, additional cost, and increases in weight and the possibility of electromagnetic interference (EMI).

Nowadays, ship designers and users are progressively looking towards other alternative in replacement for copper based cables to increases in bandwidth and at the same time to improve the networks performance especially in the area of access network. The Fiber Distribution Data Interface (FDDI) optical network technology has commonly used as the backbone optical network. This network is in support for long range data transfer and using silica fiber based. Alternatively, The Fiber-To-The-House (FTTH) technology and automobile industry has propelled the usage Polymer Optical Fibers (POFs) for the medium and short distance networks communications at gigabit rates. POF therefore, is an acceptable alternative replacement for copper, coaxial cable or even silica fiber cabling especially for the short distance applications and access network. POF is also extremely reliable and robust, quick and easy to install, inexpensive, self-powered, provides whole house coverage, work on an unlimited number of outlets, immune to electromagnetic interference (EMI). Therefore, POF is a promising mean of data communication media for current and future designed ship.

In this study, the issue of network survivability and connectivity onboard the ship will be addressed by introducing dual redundancy network topology as physical connectivity and online control and monitoring switch (MOOS) using microcontroller PIC18F97J60. The FDDI ring based optical fiber network is used as main transmission media for optical ship data transfer of LAN networks, CCTV and TV/radio entertainment onboard ship using WDM technology. The access network to the user is using POF-WDM technology complementing the FDDI backbone network. This combination optical network will be able to replace numerous and complex wiring on board the ship into the implementation of all-fiber-network. These networks are offering a huge bandwidth to support later equipments and systems extension.
Materials and Methods

Architecture:

The proposed network layout is shown in Figure 1. The FDDI optical network is connected deck-by-deck with dual redundant silica fiber backbone architecture. The POF Multiplexer Terminal Switches (MTS) are placed at important compartment namely Machinery and Damage Control Room (MDCR) at deck 1 aft, Combat Information Center (CIC) at deck 01, Bridge at deck 02, Main Communication Centre (MCC) at deck 1 amidships, ship office at deck 02 fwd and ship store at deck 3 aft. This MTS provide the switching of optical cable from FDDI to access network to the user and allow flexibility of routing in different decks of the ship to protect from outages in event of loss connection due to battle damage or defective cabling. These MTC are also act as electric-optical-electric signal converter and the nodes for the networks and equipments. The data from the equipments to the users are transferred through a functional and free Ethernet channels are alternately routed through two channels for better bandwidth utilization and network control.

![Figure 1: Deck-by-deck dual redundant FDDI backbone architecture with combination of POF-WDM access network.](image)

The deck-to-deck primary network is wired using optical fiber and interconnected to MTS located at six control compartment as shown in Figure 1. The MTS is connecting the user with POF access network cable to LAN network, telephone line, CCTV video image and central video/audio entertainments. The controller and server for ship LAN and CCTV is at MDCR, Bridge and CIC. The CCTV is used for surveillance and monitoring of flood and fire or monitoring from unauthorized entrance. The LAN will enable ship staff to access daily orders, manuals, publications, maintenance requirements and training documents from computer connection at common area or while they are in the cabins. The telephone PABX and central video/audio entertainment network controller is at Main Communication Center located at the centre of deck no. 1. The central video/audio entertainment network will be available for access by the ships’ crews while at cabin or at common area. The basic block diagram of the network system is shown in Figure 2. The MOOS is located at MDCR and bridge.

![Figure 2. Block diagrams of the system.](image)
Survivability:

Survivability in a network means the connectivity of the network is maintained although the presence of loss of multiple network components. Survivability can be divided into physical connectivity and data communication interconnection. The network physical connection is provided by providing numbers of alternative network paths that can be choose in the events of loss connectivity due to battle damage or connection defective. Data communication interconnection can be monitored and controlled by the network manager at main control centre. The proposed architecture for high survivability all-optical-network onboard the ship is shown in Figure 3. Each control centre is installed with Multiplexer Terminal Switch (MTS) that capable manually select any connection loop assigned and confirming the requirement of physical survivability network. The data communication interconnection survivability is performed by the network manager at the MDCR and the bridge using low cost online control and monitoring based on microcontroller PIC18F97J60 called Microcontroller Online Optical Switch (MOOS). The physical network connection topology using MTS and the location of MOOS presented in Figure 3. In event of any connection lost due to battle damage or cable defective, the MOOC will automatically indicate for failure of connection and the network manager at the bridge controller can select any available new route for the maintain connection. In this case the Ship Office MTS to restore the connectivity. Thus, the complete connection is restored although there is a loss connection in the primary network.

Fig. 3: Network physical connection and MOOS block diagram for survivability architecture.

PIC18F97J60 Microcontroller As Microcontroller Online Optical Switch:

The Microchip Inc PIC18F97J60 microcontroller is designed to perform an intelligent optical switch controller to control the optical signal path from any optical paths to another optical path. Optical switching is one of the major processes in optical communication to optically connecting, or aligning any one of a first group of optical fiber with any one of a second group of optical fiber, enabling an optical signal to propagate through optical interface junction from one fiber to the other. This design offer a great advantage to the optical communication application for network protection and network restoration; giving a user to control the switching time between the lines. In this design, the microcontroller system will act like a server and host the web page contain the GUI interfaces to control the optical switch. The network manager can access this web page to control the optical path through the internet network either in manual mode or automatic mode.

Microcontroller:

PIC18F97J60 is the latest microcontroller that has built-in the Ethernet module. The PIC18F97J60 has meet all of specification stated by IEEE 802.3 and fully compatible with 10/100/1000 Base-T network. PIC18F97J60 is powered by a 2.35V to 3.6V dc power supply. This microcontroller comes with 380Kbyte static RAM and 128Kbyte flash program memory, plus capable to address of up to 2Mbyte by using external memory bus. PIC18F97J60 is a 100 pin TQFP device, it has 70 general purposes inputs outputs ports and the special feature...
about this microcontroller is because of its built-in Ethernet controller module. This microcontroller comes with the full implementations of both Media Access Control (MAC) and Physical Layer transceiver (PHY) module.

The five major functional block of this Ethernet module consists:

a. The PHY transceiver module that encode and decode the analog data that is present on the twisted pair interface and send or receive it over the network.
b. The MAC module that implement IEEE 802.3 compliant MAC logic and provide Media Independent Interface Management (MIIM) to control the PHY.
c. An independent, 8-Kbyte RAM buffer for storing packet that has been received and packets that are to be transmitted.
d. An arbiter to control access to the RAM buffer for storing packet that has been received and packet that is to be transmitted.
e. The register interfaces that function as an interpreter of command and internal status signal between the module and the microcontroller’s SFRs.

**Optical Switch:**

In this design, we use P1S18B-LDD optical switch manufactured by Omron’s. This is a mechanical optical switch designed to switch an optical route of 1x8. The prism is moved by an electromagnetic actuator according to an externally generated and applied input control signal, and an optical route is switched. This P1S18B-LDD model is optically passive, operating independently of data rate, data format, and optical signal direction. This optical switch contains an electronic interface board that converts TTL input signal to the switch’s optical channel position. Three channel input terminals (D0, D1, D2) are used as channel switch and one strobe input terminal. During powering the optical switch, the high level need to supply to strobe input terminal at the same time to ensure the switch to work properly.

**Embedded Ethernet System:**

The initial designs of the system in regard to the hardware, is based on the microchip PICDEM.net 2 development board. This board uses PIC18F97J60 microcontroller with Ethernet and USART connectivity. The boards consist of numbers of components to interface the microcontroller with the optical switch and provide the microcontroller with the bidirectional Ethernet communication. The experiment board is shown in Figure 4. This board has an LCD module for display the status of the board, serial EEPROM with 256Kbyte space to store the additional data, RJ-45 port for connection to an Ethernet cable and DB9 socket for serial RS-232 communication with the PC. 9V – 12V dc regulated power supply is required to drive this board. This board is connected to the optical switch by using general input-output port. The three pin are used as data controller for the optical switch and one pin is used for the strobe pin.

![Fig. 4: Prototype of Microcontroller Online Optical Switch (MOOS).](image)
This embedded board will act as a web server which hosts the HTML, JavaScript and Ajax file that contains the instruction to control the optical switch. When the power is supply, the LCD will display the status and the IP address of the board. In the PC client, we can access the HTML page store in the system memory by inserting the IP address at the web browser.

User can control the operation of the optical switch by using these web pages to send the instruction to the board. Once the instruction from the web pages is received, the microcontroller will run the specific algorithm to control the optical switch. The web page design here has 2 ways for controlling the optical switch, either by manual switching or by automatic switching. For the manual switching, user need to specify which line or which channel want to divert the optical routing, and for auto switching, user need to select the delay of the switching time between the channel, where for this design, we has specify either 10 second, 30 second or 60 second for each delay.

Software:

The software environment consists of two parts; the C programming language to implement the microcontroller algorithm to control the optical switch by using Ethernet, and web programming language, consists of the HTML, AJAX and CSS language to communicate and control the microcontroller.

Ethernet Communication:

The Ethernet communication between the board and the PC is based on the TCP/IP protocol. Internet protocol suite (TCP/IP) is the basic communication language or protocol of the Internet, used to connect hosts on the internet. The TCP/IP is the heart of the Ethernet communication. It allows total location independence and interoperability to any embedded application. For this part, we use Microchip TCP/IP stack application to build the Ethernet application for interaction between the physical network port and application used. This board application is configured as the web server or HTTP server that is capable to serve HTML page to web browser through the network. This application is used to perform status monitoring, remote management, and data retrieval throughout the network.

Web Bases:

For the status monitoring and controlling the optical switch, the web pages are used as a GUI to communicate between the microcontroller and the operator. This can be access by remote client computer at the central office to control the path of the optical guide.

Experimental Set-Up:

The ability of the system to control the optical switch in the ship optical network via internet was tested through extensive experiment. The experiment was done by connecting the optical switch with the embedded Ethernet board and the connection between the board and Internet network is established via the RJ-45 plugged-in to the board. The experiment set-up is shown in Figure 5. When the board is powered, channel will be at default
condition due to zero logic at the address input (T1, T2, T3). The FOT-600 Optical Loss Meter will show the value of the insertion loss at the terminal 1. During this test, we used 1550 nm wavelength as a source for optical signal and we use 2 unit FOT-600 where for the first unit is to generate the optical source and measure the loss in the channel 1 and the second unit is to measure the loss in the other channel. The result of the FOT-600 insertion loss for the 8 channel is shown in Figure 6.

Fig. 5: Experiment configuration for Insertion loss in MOOS using FOT-600.

Fig. 6: Experimental result for 8 channel MOOS.

Result and Discussion

The experiment was carried out on the silica optical fiber to measure the insertion loss in comparison to the optical switch specification datasheet. The results obtained are summarized in Figure 7. The theoretical value of insertion loss for this optical switch is expected to be 2 dB, but the measured loss for 8 optical channels is at the range of 2.5 dB to 4.25 dB. The average insertion loss for 8 channels under test is 3.5 dB. The mismatch is due to the connection set-up and the termination loss. The loss can be minimized by ensuring proper termination and connection of optical cable during experimental set-up and testing in more proper environment. Insertion lost deviation is shown in Figure 8. The small deviation is found at every single optical switch and in the MOOS prototype except at line 2 when the insertion loss deviation is above than 2. The average deviation is approximately 1.5 and the value is considered small and acceptable. After considering the ring parameter as deflected in Figure 3, the total loss in the network is approximately 21.06 dB.
Conclusion:

The redundant optical network topology and Microcontroller Optical Switch (MOOS) online optical switch controller using embedded internet based system for survivability of data communication transfer was successfully introduced. The MOOS is online optical switch using a simple microcontroller PIC18F97J60 used for online monitoring and fault identification by controlling optical switch connected to the network. The proposed MOOS system architecture is discussed considering the possible hardware and software elements to develop the online switch controller. Finally, the benefits and limitations of such system were discussed using some initial results obtained in the experimental activities. This system is very promising for future development of the all-optical-network onboard the ship and other applications.

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