Australian Journal of Basic and Applied Sciences, 5(10): 146-155, 2011
ISSN 1991-8178

The Effective and Low Cost Solution for Status Determination in Multi-line Fiber-to-the-home (FTTH) Network

[1]Mohammad Syuhaimi Ab-Rahman, [2]Mastang, [3]Kamarulzaman Mat and [4]Kasmiran Jumari

[1]Spectrum Technology Research Group (SPECTECH) Department of Electrical, Electronics and Systems Engineering Faculty of Engineering and Built Environment
[2]Institute of Space Science (ANGKASA) Universiti Kebangsaan Malaysia 43600 UKM Bangi, Selangor, Malaysia.

Abstract: This paper presented the development and implementation of the effective and low cost solution for status determination of all lines in Fiber-to-the-Home. Fires in manholes, or nearby, often cause cable damage, resulting in loss of service. Accidental digging by construction crews is a frequent problem. These problems can cause customer service interruption. To minimize the problem, wireless monitoring system in FTTH has been built to monitor and detect the failure in optical line and enable the engineer to make restoration. We use 'tapping' method to obtain the optical signal from FTTH line and the signal then will be fed into the optical passive circuit that consist of WDM Coupler SM 1480/1550nm and fused coupler SM 10:90 1550nm. Testing on the development concept is carried out. From this testing, it is established that this system is capable of detecting any occurrence of failure/faults and recovery the failure links within 10 s.

Keywords: Optical line detection, FTTH monitoring, Optical monitoring, FTTH restoration, Status determination

INTRODUCTION

The telephone and cable-TV operators were determined to exploit the advantages of fiber in the network. This is because fiber has unlimited bandwidth, high quality service, future-proof and superior reliability and security. Fiber optics technology has the most bandwidth capacity. It can easily provide gigabit bandwidth. And this unlimited capacity can go both downstream and upstream (Ab-Rahman, 2009). This high capacity for upstream transmission is what no other broadband technology can offer. Optical network can provide high quality traditional telecommunication services such as telephone, cable TV, web browsing, and file transfer as well as high quality streaming video, video conferencing, video telephone, online games, etc over one single fiber. Fiber optics can provide very high bandwidth both downstream and upstream. There are unlimited possibilities for the future, for example, telecommuting or distance education. That is why people say that 90% of applications for fiber networks have not been developed yet (Devi, 2003).

Fiber to the home (FTTH) is the installation and use of optical fiber from a central point directly to individual buildings such as residences, apartment buildings and business to provide unprecedented high-speed internet access. FTTH dramatically increases the connection speeds available to computer users compared with technologies now used in most places (Smith, 2008). Three types of signal from the FTTH system that are transmitted to users are voice, data and video signal. These signals are combined using WDM method and transmitted to users through a single optical fiber. Wavelength for each data and voice signals is 1480 nm and 1550 nm for each video signal. All the combined signals are transmitted to end users through passive optical splitter with the splitter separation rate varies from 2 up to 32 users (Ab-Rahman, 2009). Passive optical network (PON) using point-to-multipoint configuration is one of the most promising solutions for fiber to the home (FTTH) due to the significantly cost reduction on active components/devices and fibers sharing (Yukihiro, 2006). Essentially, there are three fundamental architectures for delivering fiber directly to a subscriber's house: point-to-point, switched, and Passive Optical Network (PON). All three FTTH architectures require an aggregation device in the CO (the Optical Line Terminal or OLT), and all three require an optical to electrical converter (Optical Network Terminal or ONT) in or on the house. These three architectures differ mainly in what type of device (if any) is installed between the CO and the house (Bartell, 2009).

Corresponding Author: Mohammad Syuhaimi Ab-Rahman, Spectrum Technology Research Group (SPECTECH) Department of Electrical, Electronics and Systems Engineering Faculty of Engineering and Built Environment

One common characteristic of the FTTH network architectures is the use of bidirectional transceivers (BIDI) allowing the use of a single fiber to serve each home. One wavelength is used for downstream (Central Office to Home), and another wavelength is used for upstream transmissions (Home to Central Office). Bidirectional transmission on a single fiber increases the cost of optical transceivers somewhat, but it reduces the quantity of fiber (and labor to splice the fiber) needed to serve a home by half (Multicom Incorporation., 2007).

The problem always happen in FTTH is line break. Several types of breaks can also occur in underground cables. Accidental digging by construction crews is a frequent problem. Fires in manholes, or nearby, often cause cable damage, resulting in loss of service. Other cable cuts can also be the result of vandalism. In some countries, underground fiber cables even get stolen by mistake by people who want to melt the copper and sell it (Masson, 2006).

Fiber-cable breaks and degradations are really one of the main causes of network service disruptions. In order to ensure continuous service delivery to customers, we develop a system that can determine the line status by monitoring the video signal in FTTH and automatically restore the fiber fault line by switching the working fiber to the alternative line.

This system consists of optical splitter, video signal detector, wireless module and Graphical User Interface (GUI). Optical splitter is used to split the optical signal with ratio 90:10. 10 % of the signal will be used as input of video signal detector. Video signal detector can detect video signal in optical line and send it to engineer in central office via wireless. Graphical User Interface (GUI) was built with visual basic. Visual Basic is an ideal programming language for developing sophisticated professional applications for Microsoft Windows. It makes use of Graphical User Interface for creating robust and powerful applications. The practice shows that the system can monitor the condition of all lines in FTTH and send all signals to central office via wireless using multipoint-to-point protocol.

System Architecture:

The system can be categorized into monitoring and restoration system. The monitoring system is done by MADS (Multi Access Detection System) and the restoration is done by CAPU (Customer Protection Unit). The schematic diagram of this system is presented in Figure 1. MADS will send data to CAPU Controller by wireless about the condition of FTTH line. Then, the CAPU controller arranges the information in the form of packet and controls the CAPU to make restoration if there is failure in FTTH line. The CAPU Controller also sends information about FTTH line condition to CO (Central Office) over LAN.

The MADS involves WDM Coupler 1310/1480/1550nm, fused coupler 90:10 1550nm, optical signal detector and wireless transmitter. The inside of MADS is shown by figure 2. WDM functions in splitting optical signals according to their respective wavelength with 1310nm for data and voice signal and 1550nm for video signal. After these signals have been separated, output 1480nm will pass through WDM demultiplexer while 1550nm signal will pass through fused couple. WDM coupler has a very low loss, high quality and is small in size.

Optical coupler is used to split 1550nm signal in accordance to specific ratio. There are coupler with ratio of 95:5, 90:10 and 50:50. It is important to select the right coupler. For coupler with splitting ratio of 50:50, only 50% of the signal will be fed back into the trunk line. This implies that the resent signal power will be weakened and causing limited distance of transmission. Based on the matched characteristics of the coupler to the system, we choose coupler with splitting ratio of 90:10.

Optical signal detector has function to determine the optical signal in FTTH line. It can detect and convert optical signal to 1-bit signal (electrical). The 1-bit signal will be sent to the CAPU controller by wireless transmitter. In this work, an off-the-shelf communication approach is adopted based on Wireless Sensor Network (WSN) technologies. Digi's XBee-PRO RF Module (Digi International., 2006) is selected to provide the wireless communication function for the PLS module. The XBee PRO is engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low data rate, simple connectivity, and low-power WSNs. It operates at the ISM 2.4 GHz frequency band, with a maximum over-the-air data rate of 250 kbps. Due to the overhead of the protocol the actual theoretical maximum data rate is approximately half of the theoretical maximum. IEEE 802.15.4 specifies the use of Direct Sequence Spread Spectrum (DSSS) and uses an Offset Quadrature Phase Shift Keying (O-QPSK) to modulate the RF carrier. This helps to enhance the communication immunity to ambient noises, especially to those with wide frequency bandwidth, such as impulse noises commonly observed in high voltage power line environment. The 802.15.4 is a part of IEEE family of standards for physical and link-layers for wireless personal area networks (WPANs).

The WPAN working group focuses on short range wireless links, in contract to local area and metropolitan area coverage explored in WLAN and WMAN working groups, respectively. The focal area of the IEEE 802.15.4 is that of low data rate WPANs, with low complexity and stringent power consumption requirements (Shurui, 2010).

The XBee-PRO also includes ZigBee features, allowing for communication in a point-to-point, point to multipoint, or peer-to-peer configuration, and each device can be configured as a Coordinator, End Device, or Router. These features are very helpful in organizing a WSN by a cluster tree topology, which is more suitable to networks that cover larger physical areas, where no single device is able to directly link with every other device.

In general, the Coordinator acts as a central RF module that is configured to provide synchronization services through the transmission of beacons, and the establishment of membership between End Devices and a Coordinator. With its help, a large cluster tree network can self-organize into smaller subnets, each of which has a Coordinator. Data flows from an End device to its Coordinator node, through a Router node to a higher subnet, and continues upward until reaching a central collection device. At the same time, the network's ability to self-heal can be obtained, if the radio at one sensor node is removed for some reason, a new path to route message through other nodes can always be found with the help of the Coordinator.

The XBee-PRO has over 65,000 unique network addresses available to support large scale of networking. 128-bit Encryption is included to improve the communication security, and "retries and acknowledgements" scheme can help to increase the communication reliability. The RF module can operate at different modes under various conditions, each of which has different power requirement. Proper design of switching scheme between modes can help to reduce module power consumption.

To switch the optical line, we use optical switch allocated in transmission line. Figure 3 shows the inside of optical switch controller. It consists of optical switch 2x1 and 2x2. The first optical switch is used to switch the signal to protection line at local transmission or switch to protection line at transmission line nearby. The second optical switches will switch the signal in protection line back to the original path before sending in to the end of user. So the implementation of optical switches will provide continuous signal flow since the mechanism architecture employs both the protection line and neighbor's protection line. Microcontroller is used to control the activation of optical switch. Wireless receiver is implemented for data communication between Central Office (CO) and CAPU.

The optical switches from CAPU device will be activated after CAPU controller sends the failure code to CAPU device. Then, fiber fault line will be diverted to the protection line. CAPU is an intelligent device connected to the ONU to ensure survivability in the immediate split (direct to user) of FTTH-PON access network. Besides providing the self-protection, each user at the ONU needs to employ this device in order to maintain continuous network transmission. In the shared protection mechanism, when there are breakdowns occur at both working line and protection line, CAPU will find the neighbor's CAPU for a fast restoration. LAN data is used to monitor the state of distribution fiber and Ethernet switching to the protected path is performed at each ONU independently.

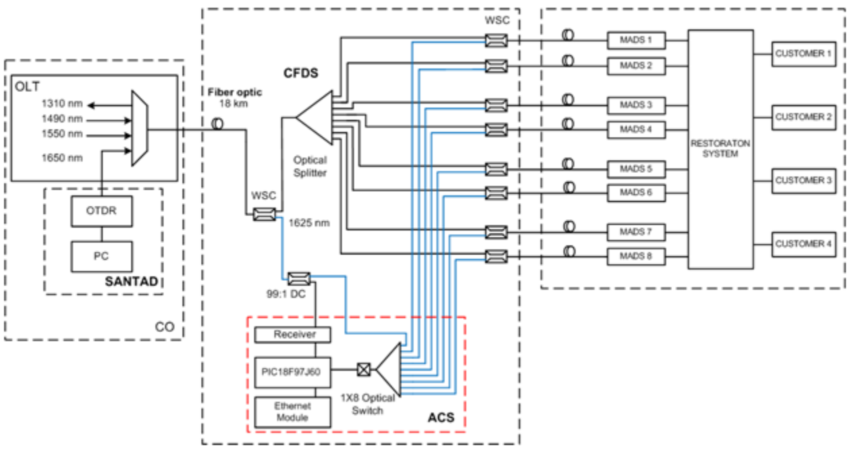


Fig. 1: Monitoring system in FTTH.

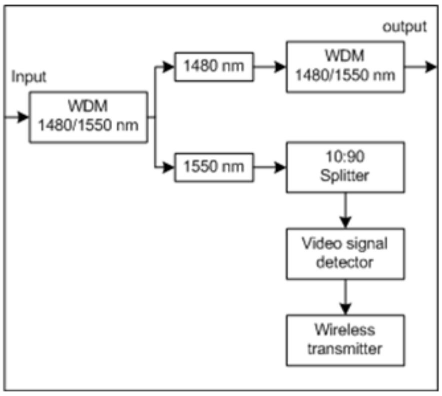


Fig. 2: Wireless Sensor.

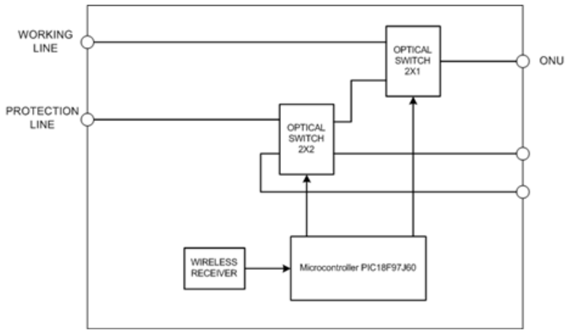


Fig. 3: The inside optical switch controller.

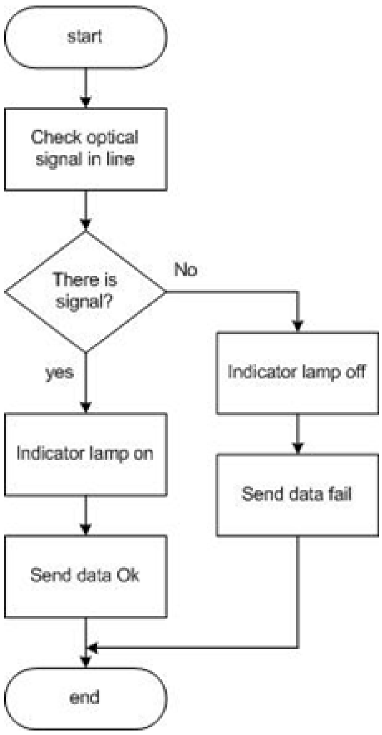


Fig. 4: monitoring mode.

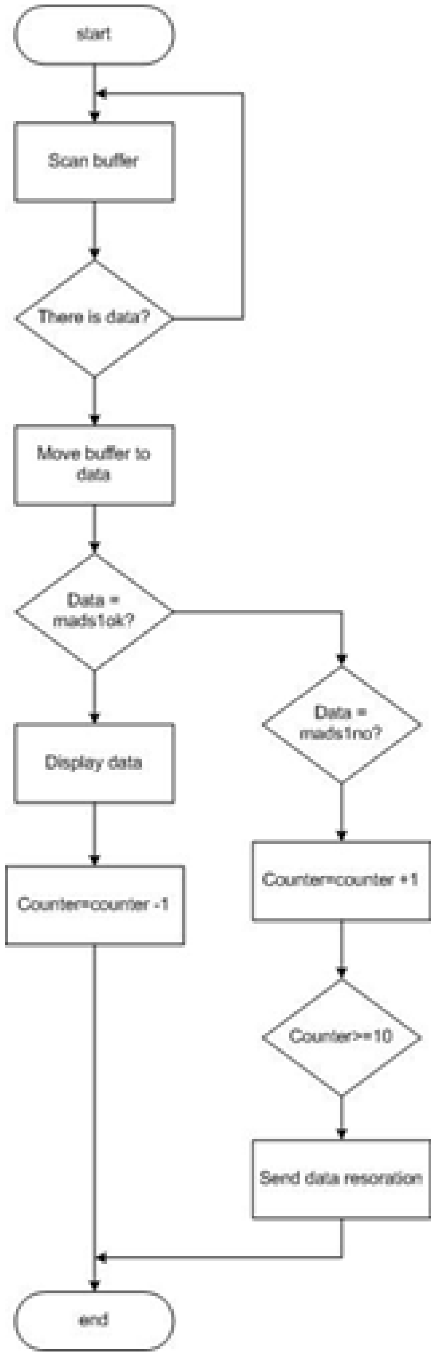


Fig. 5: Filtering mode.

Operation System:

Operations of the digital door lock are divided into four modes, monitoring, filtering, restoration and self-monitoring.

1. Monitoring:

Figure 4 shows the monitoring mode of this system. Every 10 ms, sensor will check the existence of optical signal in network. LED 3 volt is put in the sensor to indicate the output of optical sensor and send it to Central Office through wireless.

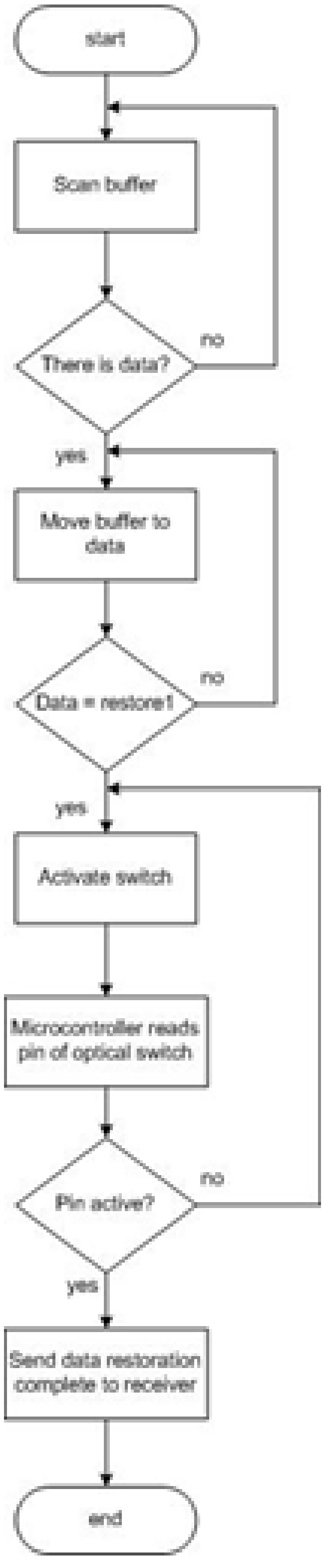


Fig. 6: Restoration mode.

2. Filtering:

Figure 5 shows the filtering mode of this system. To reduce the noise and ensure the validity and reliability of data monitoring, we use filtering algorithm. Data restoration will be send to sensor after receiver gets failed information 10 times continuously.

3. Restoration:

Figure 6 shows the restoration mode of this system. When the sensor receives data "restore" from receiver, microcontroller will activate the optical switch and then read the pin output of optical switch to ensure that the restoration has been done. The microcontroller will send data to receiver that the optical switch has been activated.

***4. Self-monitoring*:**

Figure 7 shows the self-monitoring mode of this system. All sensors will communicate each other to ensure the operation of the network. When one or some sensor are failed, the others sensor is able to detect this condition and send data to central office about which sensor is loss.

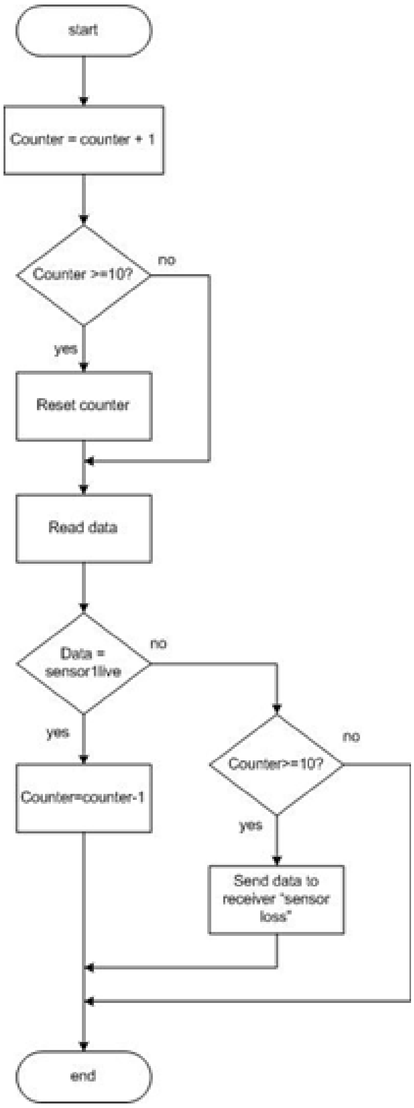


Fig. 7: self-monitoring mode.

Testing Result:
***Analysis of Video Signal Output*:**

Central office can provide video signal for 24 hours to customer so that video signal is used as reference to detect any optical line failure in FTTH. Figure 8(a) shows the output of optical video detector in which no video signal is received by video receiver. In this condition, optical video detector outputs 0 volt (logic 0). Figure 8(b) shows the output of optical detector where there is video signal in optical network. In this condition, optical video detector outputs 3.3 volt (logic 1). Figure 8(c) shows a transient response of video signal into a logic signal.

Graphical User Interface (GUI):

To display the data monitoring on computer, we use visual basic. Visual Basic is an ideal programming language for developing sophisticated professional applications for Microsoft Windows. It makes use of Graphical User Interface for creating robust and powerful applications. The Graphical User Interface as the name suggests, uses illustrations for text, which enable users to interact with an application. This feature makes it easier to comprehend things in a quicker and easier way. Figure 9 shows the Graphical User Interface (GUI) in VB that is used by engineer to monitor the optical signal in optical network.

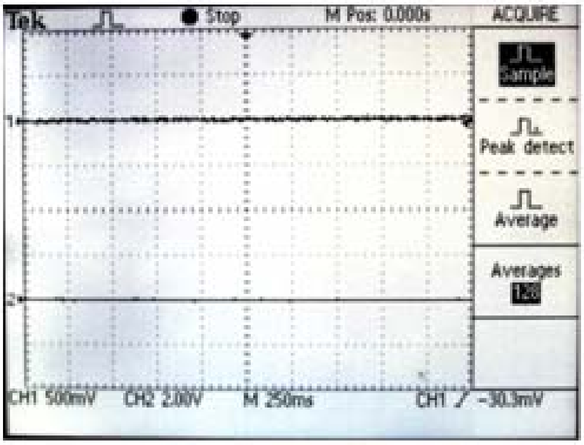


Fig. 8(a): Video detector detects no video signal.

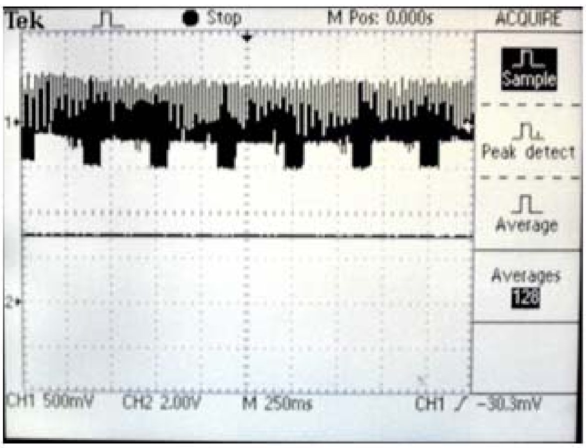


Fig. 8(b): Video detector detects a video signal.

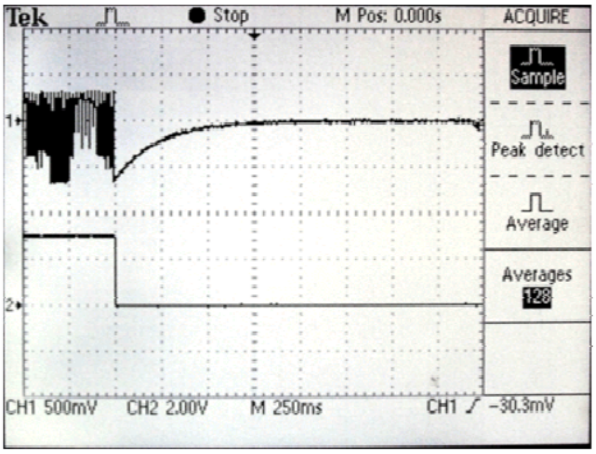
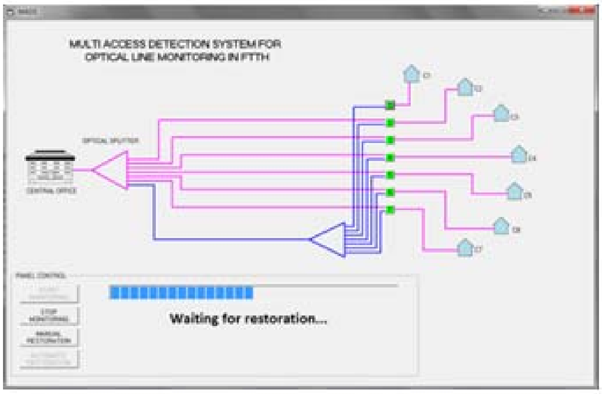


Fig. 8(c): Transient response of video detector.



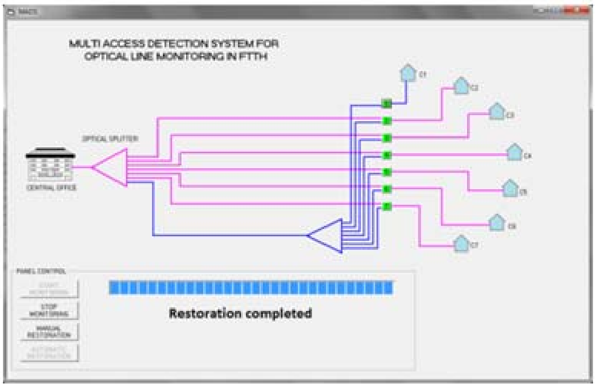


Fig. 9: Graphical User Interface of Wireless optical sensor network for FTTH application.

Conclusions:

Status determination is essential for ensuring the high-quality operation of optical access network systems. In fact, an effective and reliable optical network, such as FTTH-PON, depends on appropriate survivability. We successfully developed Multi Access Detection System with self-protection scheme for TDM-PON with operation, administration and maintenance (OAM) features in order to improve service reliability and reduce restoration time and maintenance cost.

REFERENCES

Ab-Rahman, M.S., 2009. CATV Tester Unit for Fiber-to-the-Home. International Conference on Space Science and Communication. Negeri Sembilan, Malaysia: Angkasa UKM.

Bartell, J., 2009. Three fundamental architectures for FTTH. FTTxtra. http://www.fttxtra.com/ftth/three-fundamental-architectures-for-ftth.

Devi, S., 2003. Fiber-To-The-Home (FTTH). InternetworkTechnologies. Available: http://cc.1asphost.com/geowcloo/IT/FTTH.htm

Multicom, Incorporation., 2007. Three Fundamental Architectures for FTTH. http://www.multicominc.com/stimulus/FTTH_architectures.htm.

Masson, B., 2006. Enesuring The Availability and Reliability of Dark-Fiber Networks. Canada : EXFO.

Digi International., 2006. Digi making wireless M2M easy. http://www.digi.com/products/wireless/zigbee-mesh/xbee-zb-module.jsp#overview.

Shurui, F., L. Jingbo, H. Sun and R. Wang, 2010. Throughput analysis of GTS allocation in beacon enabled IEEE 802.15.4. Proceedings of 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT), 9-11(4): 561-565.

Smith, J., 2008. Du's FTTH network one of the world's largest. Business Intelligence Middle East. Available : http://www.bi-me.com/main.php?id=20774&t=1

Yukihiro, F., 2006. Application of Ethernet Technologies to FTTH Access Systems. IEICE Trans Commun (Inst Electron Inf Commun Eng), 661-667.