



Journal of Applied Sciences

ISSN 1812-5654

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>

Analysis of Components Failure, Malfunction Effect and Prevention Technique in Customer Access Network FTTH-PON

M.S. Ab-Rahman, M. Tanra, S.C. Rosli B. Ng, A. Baharudin and S.A.M. Khithir
Spectrum Technology Research Group (SPECTECH), Department of Electrical,
Electronics and Systems Engineering, Faculty of Engineering and Built Environment,
Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Abstract: Preventive maintenance is regular maintenance which is designed to prevent the need for more costly restoration. Two major approaches for PM are time-based and condition-based maintenance. In contrast, the maintenance can be effective and more efficient type of maintenance than time-based maintenance. However, Irrespective of the approaching adopted for PM, whether a failure can be discovered early or even predicted is the significant point. Towards this objective, this study investigates the malfunctions in Fiber-to-the Home (FTTH) network in passive architecture (PON). Five important elements had been selected and identified that contribute to the system failure as the paper starting point. Critical hazard that affects the human is also highlighted. Finally we proposed four methods that can be applied to minimize the hazard by good monitoring, fast failure monitoring, effective restoration scheme and efficient maintenance by means our proposed solution such as MADS, SANTAD, CTU, OXADM and PIM. This include also caution should be taken when managing, controlling and applying activities in the fiber network. Although, the PON is the cost-efficient solution for high speed data communication but the adjustment is still needed for the safety and survivability insurance.

Key words: Component failure, malfunction, prevention technique, FTTH, preventive maintenance

INTRODUCTION

Engineers always strive to achieve high-quality and excellent-performance of a system. Reliability engineering integrates the quality and performance from the beginning to the need of the system life (Elsayed, 1996). Hence, reliability can be categorized as the time-dimensional quality of a system. Development, concept, product, quality control, shipping, installation, process and maintenance can affect the reliability. Therefore, giving attention to each of the phases increases reliability. Specifically, in the onsite operation stage, failure is the main cause of bad performance and decrease reliability. Consequently, avoid the failure is the main solution to reliability assurance (Yang, 2003). Improvement Maintenance (IM), Preventive Maintenance (PM) and Corrective Maintenance (CM) are the main types of maintenance (Patton, 1983). The function of Improvement maintenance is to eliminate-entirely the demand of maintenance. IM is placed at the design phase of a system and stresses elimination of failures. There are many limitations for a designer, however, such as place,

budget and market demands. Generally product reliability is dependent on the product price. On the other hand, CM is the restoration performed after failure happens. PM means all actions intended to protect equipment in good operating condition and to avoid failures (Patton, 1983). PM should be able to indicate when a failure is about to occur, so that restoration can be performed before such failure causes damage or capital-investment loss. Hence, PM is an effective solution to promoting reliability (Rao, 1992). Time-based and condition-based maintenance are 2 major approaches for PM. In contrast, condition-based maintenance can be a better and more cost-effective type of maintenance than time-based maintenance (Yang and Liu, 1998). Irrespective of the approach adopted for PM, the key point is whether a failure can be detected early or even predicted. If the predicted future state-variables indicate a device is going to fail, then the failure can be prevented in time by PM. Nevertheless, future-state variables should be accurately predicted at a reasonably long time ahead of failure occurrence (Willsky, 1976; Isermann, 1984).

Corresponding Author: Mastang Tanra, Computer and Network Security Research Group, Department of Electrical, Electronics and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
Tel: +603-89216448 Fax: +603-89216146

FTTH, or Fiber-to-the Home, refers to fiber optic that replaces the copper wire of the local Telco. FTTH is desirable because it can carry high-speed broadband services integrating voice, data and video and runs directly to the junction box at the home or building. For this reason it is sometimes called Fiber-to-the Building, or FTTB. Traditional copper telephone wires carry analog signals generated by telephone equipment, including fax machines. Analog technology is by nature a less precise signaling technology than digital technology. Though multiplexing has allowed digital signals to be transmitted across multiple channels over copper lines, fiber optic cable is superior for relaying these signals and allows for faster transfer rates and virtually unlimited bandwidth. This opens the door to better Internet speed, streaming video and other demanding applications.

The Internet utilizes a backbone of fiber optic cables capable of delivering incredible bandwidth. This inherent ability makes the Internet a prime source for advancing network technologies that can be brought to the home or business. Most subscribers, however, log on to this network through copper lines with limited capacity. This creates a bottleneck for advancing technologies that increasingly require greater bandwidth. FTTH bridges this gap. Fiber optic cables are made of glass fiber that can carry data at speeds exceeding 2.5 gigabits per second (Gbps). FTTH services commonly offer a fleet of plans with differing speeds that are price dependent. At the lower end of the scale, a service plan might offer speeds of 10 megabits per second (Mbps), while typical DSL (Digital Subscriber Line) service running on existing copper lines is 1.5 Mbps. A more expensive FTTH plan might offer data transfer speeds of over 100 Mbps that's about 66 times faster than typical DSL.

Due to the increasing demand in capacity or popularly called bandwidth as effect of increment of services and applications offered by service provider today, laser is the suited carrier signal and modulation scheme that can fulfilled this requirement. Although the current achievement in laboratory is for customer access network is 10 Gbps, as contrary to the commercialization achievement which is 2.5 Gbps, optical fiber is the best medium to carry this fastest communication traffic. Because laser operates in this technology are in range of invisible, therefore their impact to the system performance and customer are crucial if breakdown happened in the network. Towards this issue, this research is aiming to study the failure and risk in passive customer access network, FTTH-PON. Five significant elements had been chosen and identified that contribute to the system malfunction as the paper starting point. Critical hazard that gives effect to the human is also highlighted. Finally, we proposed three techniques that can be used to be

embedded in the existing system to reduce the risk by excellent monitoring, reliably restoration scheme and efficient maintenance. This include also caution should be taken when handling, operating and implementing activities in the active fiber test field. Our proposal is expected can reduce the risk of injury and data corrupted towards the minimum level.

RETINA INJURY REGION AND EXPOSURE LIMIT

The retina hazard region covers wavelengths from 400 to 1400 nm. The cornea-lens combination may increase the irradiance at the targeted tissue with a factor of up to 10^5 and cause permanent blindness if there is critical exposure to retina. To avoid the potential hazard, the light source should not exceed the standard exposure limit permitted by International Commission on Non-Ionizing Radiation Protection (ICNIRP). However, the relaxation of the exposure limit is permitted by ICNIRP if light source are subtended with a large angle. These sources can be an array of laser diodes, LEDs and reflection from a large area. As stated in ICNIRP, the minimum allowable angular subtense where the relaxation can be applied is 1.5 milliradian. The angular subtense, α is the angle subtended by an apparent source at the eye or point of measurement. The angular subtense at 10 cm is given in Eq. 1:

$$\alpha_{src} = \sin^{-1} (I \times w)^{1/2} / 10 \text{ cm} \quad (1)$$

where, I is the length and w is the width of the source in cm (International Commission on Non-Ionizing Radiation Protection 2000). Any light source with α beyond the minimum angular subtense ($\alpha_{min} = 1.5$ milliradian) is considered as an extended light source (International Commission on Non-Ionizing Radiation Protection, 2003; O'Hagan *et al.*, 2002), with large sources having α more than 100 milliradian. The ratio of the maximum angular subtense to the minimum angular subtense (100 milliradian/1.5 milliradian = 66.76 is the maximum allowable relaxation for exposure limit.

The maximum relaxation that allows for the exposure limit is the ratio of the maximum angular subtense to the minimum angular subtense (100 milliradians/1.5 milliradians = 66.67). This means that source with $\alpha > 1.5$ milliradians allows 66.67 times more exposure limit.

To calculate the retina exposure limit, we have to consider what kind of light source is used. Two cases need to be considered when calculating the retina exposure limit: $\alpha < 1.5$ and $\alpha > 1.5$ milliradian. When the angular subtense, $\alpha < 1.5$ milliradian, the equation for long term viewing is given by International Commission on Non-Ionizing Radiation Protection (2000).

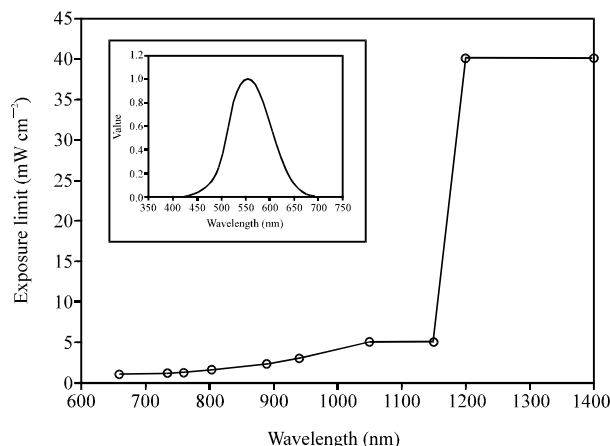


Fig. 1: ICNIRP and IEC exposure limit for long-term viewing, $\alpha < 1.5$ milliradian, retina hazard region. The insert upper left plot is the spectral luminous efficiency function for photopic vision (360 to 830 nm) and is normalized to one at its peak at 555 nm

$$EL_{eye, \alpha < 1.5} = 1.0 C_A C_C \text{ mW cm}^{-2} \quad (2)$$

where, λ is the wavelength and C_A and C_C are spectral correction factors. Spectral correction factors Eq. 3 are defined as:

$$C_A = 10^{[0.002(\lambda - 700)]} \text{ if } \lambda = 700\text{-}1050 \text{ nm}$$

$$C_A = 5 \text{ if } \lambda = 1051\text{-}1400 \text{ nm}$$

$$C_C = 1 \text{ for } \lambda < 1150 \text{ nm}$$

$$C_C = 10^{[0.0181(\lambda - 1150)]} \text{ for } 1150 < \lambda < 1200 \text{ nm}$$

$$C_C = 8 \text{ for } 1200 < \lambda < 1400 \text{ nm}$$

$$C_E = \alpha / \alpha_{min} = 66.67 \text{ when } \alpha = 100 \text{ milliradian}$$

The retina exposure limit is shown in Fig. 1 as a function of wavelength for long term viewing $\alpha < 1.5$ milliradian. Long term viewing is defined as 30 ks (8 h) continuous exposure to the optical source (International Commission on Non-Ionizing Radiation Protection, 2000). When the angular subtense, $\alpha > 1.5$ milliradian, the exposure limit for long-term viewing is given as:

$$EL_{eye, \alpha > 1.5} = 1.8 C_A C_C C_E T_2^{-0.25} \text{ mW cm}^{-2} \quad (3)$$

where, C_A , C_C and C_E are spectral correction factors, $T_2 = 10$ sec for $\alpha < 1.5$ milliradian; $T_2 = 100$ s if $\alpha > 100$ milliradian.

Since, the optical source is directly shone on the maternal abdomen, the exposure limit for skin is also calculated. It is important to know this limit to prevent any thermal injury to the maternal abdomen is occurred.

COMPONENT FAILURE

Component 1: Optical fiber cable: Fiber optic cables are composed of one or more transparent fibers enclosed in

protective coverings and strength members. Cable types can include simplex, duplex, multifiber, patch cord and bare fiber. Simplex cables are fiber optic cable with a single optical fiber. Duplex cables are fiber optic cable with two optical fibers. Multi fiber cable is a fiber optic cable with several optical fibers. Patch cords are short lengths of fiber optic cable with connectors. Bare fiber refers to a fiber optic core and cladding only. Fiber types can be single mode or multimode. Single mode describes a fiber with a small core, only a few times the wavelength of light transmitted that only allows one mode of light to propagate. It is commonly used with laser sources for high speed, long distance links.

Multimode describes a fiber with core diameter much larger than the wavelength of light transmitted that allows many modes of light to propagate. Commonly used with LED sources for lower speed, short distance links. Common connector types for fiber optic cable include bionic, D4, ESCON, FC, FDDI, LC, loopback, MTP, MT-RJ, MU, SC, SMA and ST. Some fiber optic cable comes without connectors. Important parameters to consider when searching for fiber optic cable include fiber core size, cable diameter and cable weight. Fiber core size is the size of the light-conducting central portion of an optical fiber, composed of material with a higher index of refraction than the cladding. The core size is smaller for single mode and larger for multimode fibers. Cable diameter refers to the diameter of the fiber optic cable including jacket.

Cable performance specifications to consider when searching for fiber optic cable include wavelength, numerical aperture, maximum attenuation and bending radius. The wavelength refers to the wavelength that the cable was designed for. Numerical aperture is the light-gathering ability of a fiber; the maximum angle to the

fiber axis at which light will be accepted and propagated through the fiber. The measure of the light-acceptance angle of an optical fiber, $NA = \sin a$, where A is the acceptance angle. NA is also used to describe the angular spread of light from a central axis, as in exiting a fiber, emitting from a source, or entering a detector. Maximum attenuation is the decrease in signal strength along a fiber optic waveguide caused by absorption and scattering. Attenuation is usually expressed in dB/km. Bending radius is the smallest radius optical fiber or fiber cable can bend before increased attenuation or breakage occurs. Common features for fiber optic cable include polarization maintaining, graded index and metalized. A polarization maintaining cable has fiber that maintains the polarization of light that enters it. A graded index fiber optic cable has optical fiber in which the refractive index of the core is in the form of a parabolic curve, decreasing toward the cladding. Metalized fibers are coated with metals for increased temperature resistance, soldering and harsh environments. An important environmental parameter to consider is the operating temperature.

What makes the equipment malfunction?: Most of the faults in the fiber optic cable are due to the fiber breakage, due to excessive bending or unintentional cut. Fiber cut can be caused by errant backhoes, storm damage or gnawing animals.

What are the Effect/Hazard?

Invisible light: Dangerous situations arise when untrained people pick up a live fiber and look directly into it. They see no light. Therefore, they assume there's no danger. However, such unsuspecting people can end up with a burned retina in a very short time.

Microscopic glass needles: If a person is accidentally jabbed with one of these open fibers, he could easily end up with a painful sliver. What's worse is this sliver may not be visible. These slivers are made of transparent glass and can be very difficult to see. The more real danger is when fibers are stripped, trimmed and cut. These operations result in short, nearly microscopic pieces of glass lying around a work area. These are short, thin, invisible needles. If they're left lying around, someone will inevitably end up touching or handling them. As sharp and thin as these glass shards are, they can easily penetrate the skin. And unlike a wood sliver, these glass slivers will not degrade inside the skin. These cut pieces of fiber are very dangerous. If they were to end up as lunch, they could cause internal bleeding and conceivably death.

Component 2: PLC 1XN splitter

Function: Optical Power Splitter is a component that splits the optical power in one optical route into a few different routes according to a certain allocation ratio. PLC splitters are based on the Planar Waveguide Technology. The products have ultra-low Polarization Dependent Loss (PDL), low insertion loss and high uniformity. Passive Optical Network (PON) is one of the most important standards that set up for the fiber access network or FTTH application. PON has the following advantages:

- The optical transmission has no power requirements or active electronic parts once the signal is going through the network. It greatly decreases the cost for network service operation and maintenance
- It provides services to multiple end users with one optical fiber. The services include data, telephone, video and other value increment services
- Passive devices make the network more reliable and stable in a long term
- It has good capacity scalability and easy for network upgrade

From the features described above, PLC Splitter is the best device choice for the FTTH applications. It can solve many key factors encountered in the development of FTTH and PON networks.

What makes the equipment malfunction?

- There is a fault along the feeder cable located before the splitter
- Problem relates to the distribution fiber located between the inactive ONT and the 1xN splitter
- The PLC type optical splitter unit could be damaged if the distribution cabinet is damaged
- The splitter is not in the operating range (lifespan of 30 years, 25°C and 90% relative humidity)

What are the effect/hazard?

- Power distribution interruption - Inactive ONT
- Fiber equipment frequently share facilities with power conductors (whether on poles or in underground raceways), so working in such confined spaces pose hazards such as induced voltages, explosive gases, or energized equipment or cables

Component 3: High power optical amplifier

Function: HFA is a high power fiber amplifier for FTTH/CATV application. In HFA there is a multimode

clad-pumped Er-Yb fiber amplifier, its total output power can go up to 33dBm with easy maintenance, thus it can be used for different FTTH/CATV applications.

What makes the equipment malfunction?

- **Heat:** Since, optical amplifier generates high amount of light, it does generate high amount of heat as well. Unmanaged heat will eventually breaks down the amplifier
- Pumping source is damaged
- It is desirable that the input and output end faces of the amplifying medium of the optical amplifier are inclined with respect to the optical signal transferring direction. In this case, the optical signal incident on the amplifying medium is not oscillated within the amplifying medium

What are the Effect/Hazard?: Highly intense invisible radiation is emitted from the optical amplifier if it is faulty.

Component 4: DWDM optical transceiver: DWDM Optical Transmitter is ideally suited for use in HFC and FTTH and many other fiber optic-based data, video and voice networks, including Broadband Stimulus and FCC National Broadband projects and applications. The 1550 nm transmitter now enables network operators to provide a more cost effective PON solution in FTTH applications. The equipment receives the RF signal and converts them to the optical signal by means of modulation. The signal then send to the optical amplifier to amplify the signal before injected to the OLT.

What makes the equipment malfunction?

- **Damage:** The transceivers are rugged but not unbreakable. Make sure the transceiver is neatly mounted to avoid it being biffed, nudged, cuffed, jostled, pummeled, walloped or buffeted. Cover the optical transmission or optical reception module or optical transmission/reception module and the power supply filter with metal covers to enhance the shield. At this time, make sure the module's case does not come in contact with the metal cover
- Bad power supply unit: The transformer needs a checking
- E1 line is broken
- Large current flow into the device. Do not connect the output pins directly to the power supply or GND. If the output pins need to be pulled up or pulled down, be sure to connect a resistor

- **Noise:** If power supply ripples are large, enhance the noise filter connected to the power supply line

What are the effect/hazard? Once the signals get affected by noise, signal strength gets degraded, counting for high BER. If there is large current into the device, there is a tendency of electric shock.

Component 5: Fiber optic modem: The fiber optic modem is designed to provide fiber connection for communication equipment with V.35 Interface. Capable of transmitting synchronous data with external clock at speeds from 1 Kbps up to 2.048 Mbps, the optic modem can also be set to transmit asynchronous data at speeds from DC up to 64 Kbps. In synchronous mode, the optic modem encodes the data with the clock pulse, received from the V.35 interface, into serial data stream and sends out to the optic transmitter. In asynchronous mode which has no external clock signal, the modem encodes the data with its internal clock.

What makes the equipment malfunction?

- Lightning related damage
- Dusty environment and liquid spills
- Faulty modem configuration
- Modem power transformer breakdown
- Pins and power cord where it plugs into the back of the modem could be not fully inserted, bent or broken

What are the effect/hazard? Intermittent operation. The device is on and suddenly shuts down after some time frame.

Component 6: Optical adaptor and connector: Fiber optic connector is used to connect among fiber cable. One of the advantages of using optical connector is the lower loss and lower cost compared with another method. It was really a pin vise holding a stripped fiber. The nose piece is spring loaded and was pushed back when the connector was inserted into mating adapter. The fiber stuck out into a drop of index matching fluid on a plastic lens. Typical used of optical connector in FTTH is ST, SC, MT-RC and FCPC.

What makes the equipment malfunction? Might be one of the pin is broken, which may cause the wavelength fail to reach to the destination cable.

Over voltage from input power can cause the connector cable to be burn. The power that can be

coupled from one fiber to another is limited depending on the number of modes that can propagate in each fiber.

Joint and connector lost. Each connector have their own loss depends on the mechanical alignment between the two optical waveguide and their geometric. That is why we need to do a perfect alignment.

What are the Effect/Hazard?

- Impact of the performances if the optical fiber connector is malfunction
- The connection will fail because the propagating mode need pass through the pin before they can propagate to another optical fiber
- Data transmission failed, because of the mode failure
- Power will have some loss and affect the performance of the connectivity
- When the first fiber is carrying optical energy, such energy can be emitted from the end of the fiber connector and pass through the unoccupied build out block or coupling adapter to the side of the panel where connections are to be made. This optical energy can be harmful for the operator or installer and can be especially harmful to his or her eyes. This hazard is most prevalent when as active connection has to be repaired, cleaned or otherwise altered by removal of an existing fiber connector and replacement with another

SPECTECH PREVENTIVE TECHNOLOGIES

To avoid any injury happens as well as data suffers, three actions have to be taken immediately. This means the conventional passive optical network must be embedded with new elements for monitoring, restoration and maintenance. This section proposed the three suggestion techniques that can be implemented to ensure the fiber landed to premises has low possibility of risk.

Centralized monitoring system: The remotely controlled optical switch is the key towards the centralized monitoring/troubleshooting of passive optical network by means of new developed devices; Access Control System (ACS) (Premadi *et al.*, 2010). ACS used the switch to divert the OTDR's signal launch at the Central Office (CO) to each specific line to determine the status. The result will be accumulated and display onto one screen with the assistance of our developed program named as Smart Access Network Testing, Analysis and Database (SANTAD) (Rahman *et al.*, 2009a; Chuan *et al.*, 2010). SANTAD stores the analysis results in database for further processing and queries. All kinds of additional

information can be easily accessed and queried later. The database system enable the history of network scanning process be analyzed and studied by the field engineers. With SANTAD database, the histories of scanning able to be recalled and further analysis can be conducted. By in-service monitoring with SANTAD, the field engineers can view the service delivery and detecting any breakdowns as well as other circumstances via summarized the daily and monthly network performance, which may require some promptly action before it turns into big trouble and causes a tremendous financial loss (Rahman *et al.*, 2010).

The result is display on computer screen located at the CO for further action. Figure 2 shows the example of display results from the OTDR test on our FTTH lab test bed. The box displays at the centre is noticing about the breakdown and its location in the specific line. Therefore, the status of each line can be determined simultaneously at a time by using our proposed design (Rahman *et al.*, 2010).

Fast failure detection: A fault detection method for multiple access communication is proposed. By using the occupancy term of a time-domain equalized signal as a detection system. The MADS is embedded in ACS used to detect any line fault occurs in the network which purposely focused on Passive Optical Network (PON). MADS used the tapping mechanism to verify the status of each line by using 10 dB couplers. With the assisting of optical switch matrix and microcontroller system, the status of each line connected to ONU will be identified. The result is the fault number represent occupancy counter which means the number of none traffic flow detected in the specified line during the detection process.

MADS plays an important role in failure detection in Access Control System (ACS). Although the mechanism is more on monitoring and detection but with the combination of SANTAD, the error occurs in the line can be sensed efficiently. Figure 3 shows the prototype of MADS that contains of passive optical component and electrical device. MADS takes 10% optical signal and send it to central office for monitoring and analyzing. Figure 4a and b show the experimental result of optical line monitoring. Figure 4a shows the condition of monitoring status when there is no failure in network and optical receiver can display video clearly . The circle on screen will be colored with white. Figure 4b shows the condition when optical line 2 is failure. No video signal in optical receiver and MADs will send the status to screen. The circle on screen will be colored with red when the line connected to specified MADS is breakdown (no signal).

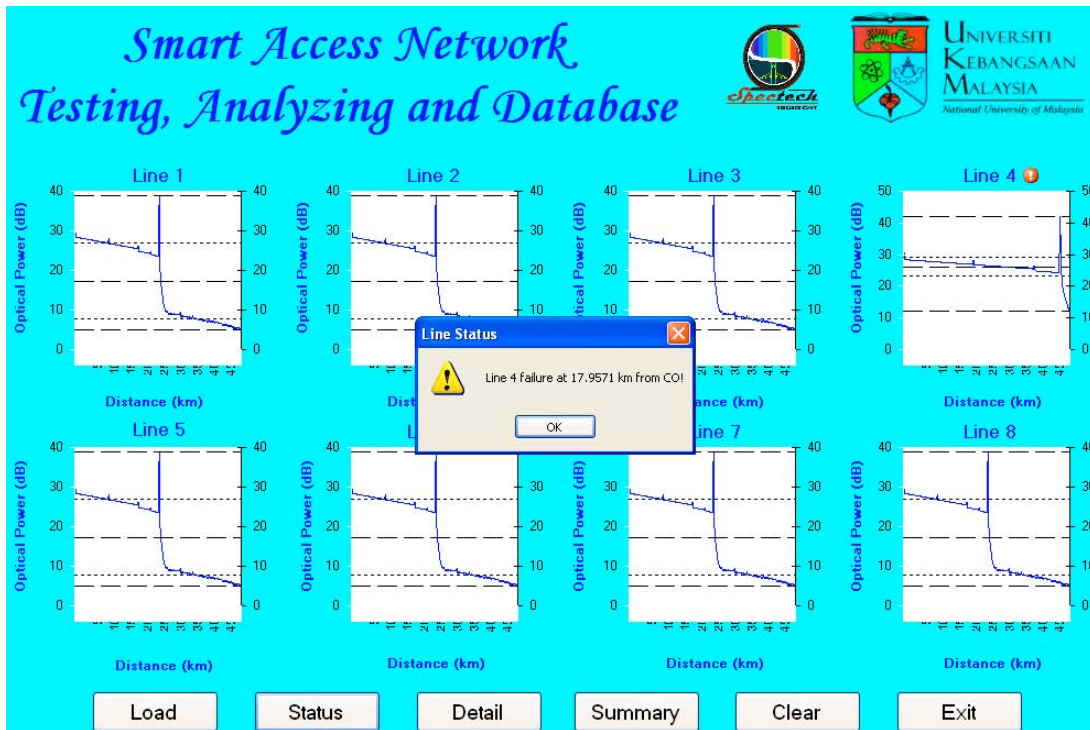


Fig. 2: Analysis of the relationship between network failure rate and network performance



Fig. 3: MADS prototype developed to detect failure which occurs in the active FTTH's line

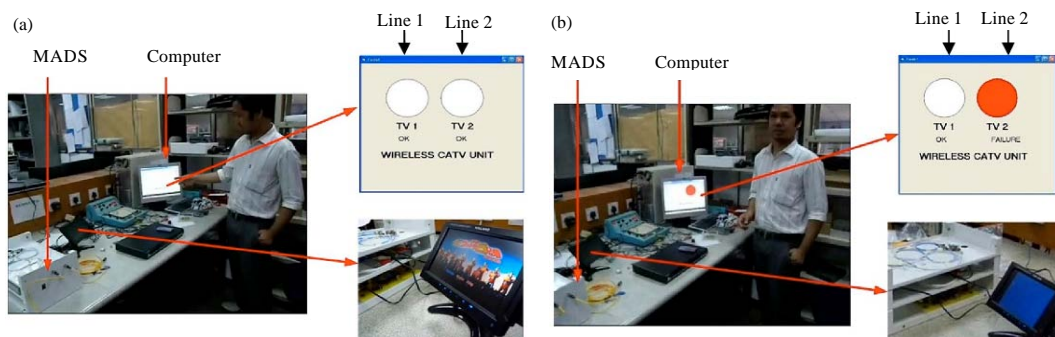


Fig. 4: Experimental of fault detection by using MADS handling by one of our engineer. Disconnection of fiber line will trigger the transmitter to send message to receive for further activation system

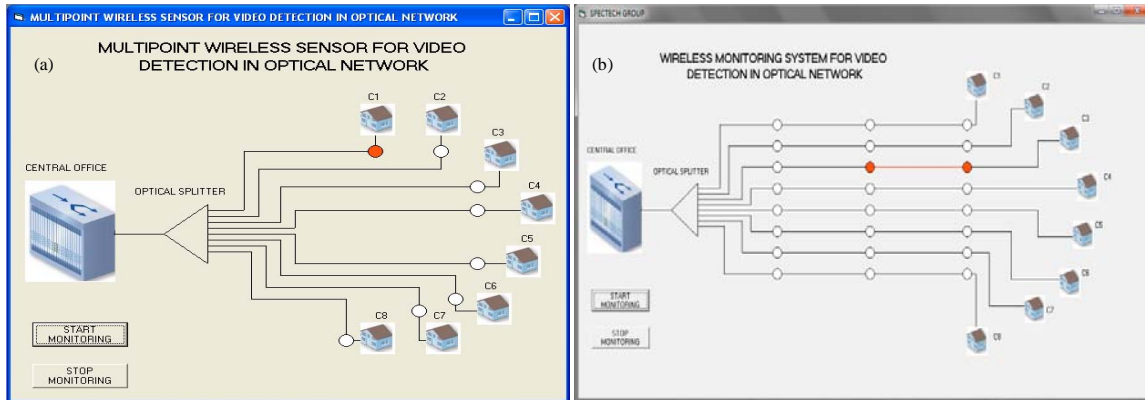


Fig. 5: When the line fails, the red circle appeared on screen to indicate misconnection happen in the system. (a) Single MADS installation enable the service provider to determine the status of each line and (b) multiple MADS installation assists in identifying the location of the failure

Figure 5a and b show the Graphical User Interface (GUI) that has been developed to increase the performance of MADS. Figure 5a shows the installation of MADS in FTTH network to monitor each line. This system can give information to engineer which line is failure. Figure 5b shows the installation of multiple MADS in FTTH network to monitor the location of failure line. This system can simplify the engineer's work to change the break optical line. Any failures occur in the system will be detected for the restoration activation while the status of each line can be monitored on screen at the service provider's office. When the line already be repaired, the red circle will turn back to white to indicate the traffic is continued flow.

Fast restoration scheme: In dedicated protection FTTH-EPON scheme, each ONU is connected to splitter output terminal by two fibers; working line and protection line through two OXADM switches that is controlled by ACS. The function of Optical Cross Add and Drop Multiplexer (OXADM) is to switch the signal to the protection line when failure occurs in the working line. The route depends on the restoration mechanism that is activated according to the types of failure (Rahman *et al.*, 2006).

Figure 6a depicted the signal flows through the working line in normal condition for both line A and line B. The OXADM switches are in bypass state that allows signals to pass through the device and be received at ONUs. The two OXADMs are allocated in the transmission line in which both ONU and splitter are located. First OXADM is used to switch the signal to protection line at local transmission or switch to

protection line at transmission line nearby. The second OXADM will switch the signal in protection line back to the original path before sending it to the local ONU. When the failure occurs in the working line, the first OXADM will switch the signal to the local protection line and the second OXADM will be activated simultaneously to switch the signal back to the transmission line. The restoration scheme is referred to dedicated protection similar to that deployed in ring configuration. Figure 6b shows the mechanism of dedicated protection in FTTH access network.

Figure 6 shows the shared protection scheme which diverts the signal to the adjacent protection line. The interruption in both working and protection lines need the shared protection scheme to be activated. The first OXADM is activated directly but the second OXADM is activated by sending the activation signal utilizing the adjacent protection line by ACS. The protection line is connected to the drop-port of OXADM 1 and add-port of OXADM 2 and it will become the third route of transmission in case of both local lines breakdown.

The proposed restoration functions above are essential for ensuring signals flow continuously and survivability of drop region in optical access network. The architecture of restoration scheme embedded in the FTTH-EPON is illustrated in Fig. 7. We proposed also low cost protection scheme that can be embedded in FTTH-PON by using simple optical switch. The proposal can be seen in (Rahman *et al.*, 2009b). The improved technique able to restore the failure up to five conditions. By using reliably and efficient restoration scheme, the risk of injury can be reduced to minimum without corrupting the data transmission.

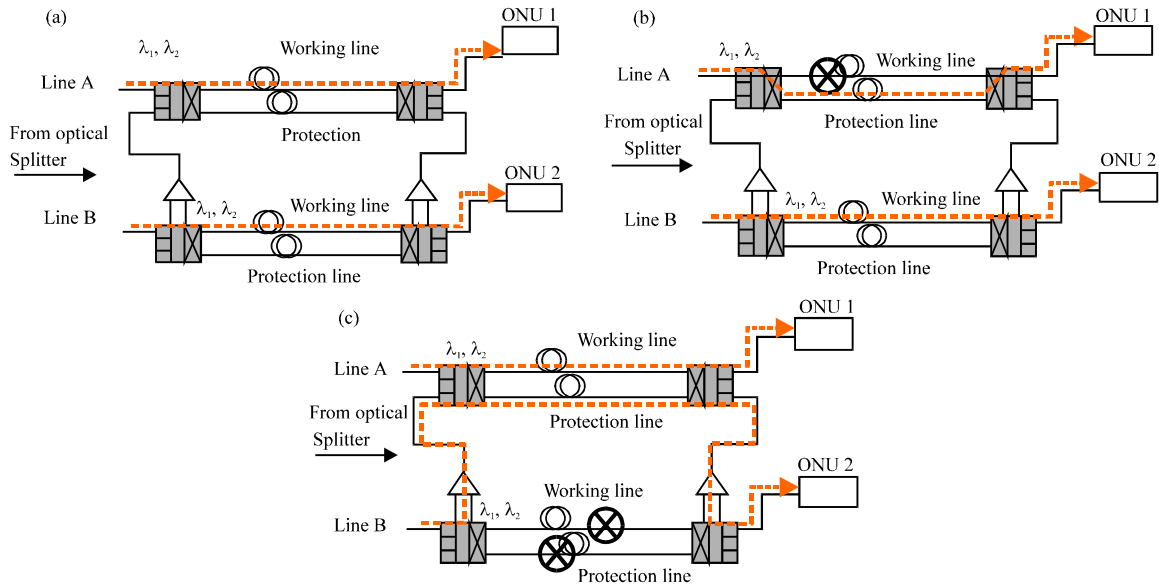


Fig. 6: Mechanisms of protection in FTTH-PON access network in normal condition and two different breakdown locations. (a) Normal condition, (b) Breakdown at working line in Line A and (c) Breakdown at both working line and protection in Line B

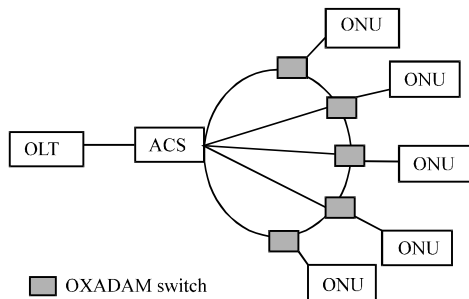


Fig. 7: The architecture of restoration scheme implementing in drop region for FTTH-EPON

Prompt action of repairing and maintenance: The Passive In-line Monitoring (PIM) devices will be installed on every node with the main lines permanently in the FTTH access network. The upstream or downstream signals from the FTTH trunk line will be entering the taper circuit. The PIM device provides a visual way of monitoring the receiving signal performance, when connected to a small television (TV) screen which the user can view the broadcast channel of CATV video or PDA for data communication. It taps out a small ratio of these signals in order to monitor the status along the main line without affecting both upstream and downstream transmission (Rahman *et al.*, 2009c).

The technicians only need to bring a portable tester unit to test the transmission signal from Central Office.

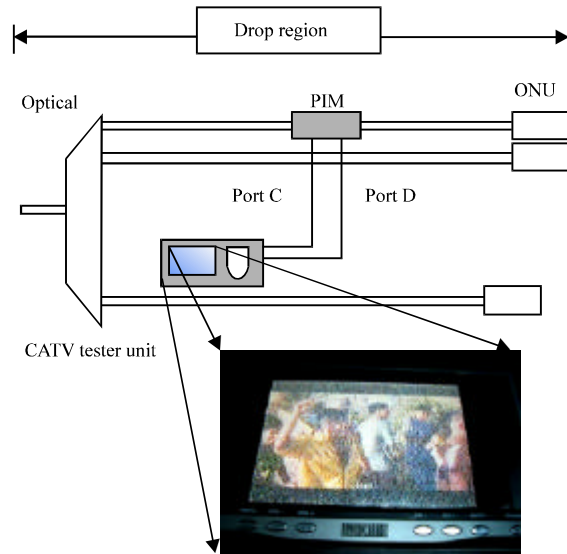


Fig. 8: PIM and CATV Tester Unit (CTU) work together with fast operational to monitor the line status and also useful to ensure the exact location of failure in the line

The PIM device enables the status of each fiber to be monitored through a portable tester unit by connecting the port C and D to a mini CATV and PDA. As indicates in Fig. 8, the output signals from port C and D are connected to a portable tester located at central office (CO). The portable tester can be shared by different PIM

device by the use of space-division devices or other suitable devices (e.g., optical selector). The optical selectors can be mechanical integrated optic switches. It allows the field engineers to identify the faulty fiber and failure location without making a site visit to. One there is any fiber fault or system downs reported by the subscribers, it enables the field engineers to firstly determine the problem occurs in which respective region and the exact failure location will be verified by an OTDR. A CATV tester unit (CTU) prototype, as depicts in Fig. 8, was developed in this research work for testing the video signal in the proposed surveillance scheme. The faulty fiber in the FTTH access network was firstly determined by the CTU and then the exact failure location (break point) was identified through OTDR.

CONCLUSIONS

FTTH or fiber-to-the-home describes a telecommunications system in which a communications path is provided over optical fiber lines extending from the telecommunications operator's switching equipment to (at least) the boundary of the home living space or business office space (the side of the building or unit). This communications path is offered for the purpose of carrying telecommunications traffic to one or more subscribers and for carrying one or more services (for example Internet access, telephony and/or video-television). Optical Fiber Pave the way for securing broadband access. FTTH technologies will allow access to more customers at higher speeds and over longer fiber length. Fiber deployment to residences is a big investment that should last for the next 30 to 40 years. Although, every deployment scheme for FTTH has its own merits, there is a high risk that short-term savings in the fiber infrastructure from PON FTTH deployments will significantly impact the future use of the expensive fiber infrastructure without major follow-on investments. The impact of the system when equipment damaged are: Strong fluctuations in laser output power, Potential permanent damage to the laser, Interference at the receiver end, Distortions in analog video signals, Higher BER in digital systems, Cost per subscriber increased, radio frequency interference, Voltage surges and corrosion caused by moisture, Voice service (telephone), Data (Internet), Video (TV, CATV) will lost by equipment damaged in FTTH. Therefore, study introduced three techniques that can be applied to reduce the number of injured. Besides that, proper and careful handling, operating and implementing activities will reduce the risk and avoid hazardous and super monitoring system enable any fault occurs in the network can be immediately

detected. While, the traffic will divert to alternative path when failure occurs in the line to ensure the communication signals flow continuously by means of smart restoration scheme. This induced the risk in the system towards the zero (no risk).

Performance monitoring, detection and restoration are important for ensuring the high quality performance of optical access network systems. In fact, an efficient and reliable optical network, such as FTTH-PON, depends on appropriate survivability. During the construction phase, proper testing is the only way to guarantee that all the required transmission specifications are met, the network is ready for actual traffic and subscribers are provided with the expected service quality.

ACKNOWLEDGMENTS

This research work was supported by the Ministry of Science, Technology and Innovation (MOSTI), Government of Malaysia, through the National Science Fund (e-Science) 01-01-01-SF0493 and Ministry of Higher Education with grant number UKM-RRR1-02-FRGS0001-2007.

REFERENCES

- Chuan, N.B., M.S.A. Rahman and A. Premadi, 2010. Development of monitoring system for FTTH-PON using combined ACS and SANTAD. *Int. J. Commun. Syst.*, 23: 429-446.
- Elsayed, E.A., 1996. *Reliability Engineering*. Addison Wesley Longman, England.
- International Commission on Non-Ionizing Radiation Protection, 2000. Revision of guidelines on limits of exposure to laser radiation of wavelengths between 400 nm and 1.4 μ m. *Health Phys.*, 79: 431-440.
- International Commission on Non-Ionizing Radiation Protection, 2003. ICNIRP statement on light-emitting diodes (LEDs) and laser diodes: implications for hazard assessment. *Health Phys.*, 78: 744-752.
- Isermann, R., 1984. Process fault detection based on modeling and estimation methods-A survey. *Automatica*, 20: 387-404.
- O'Hagan, J.B., C.M.H. Driscoll and A.J. Pearson, 2002. Occupational Exposure to Optical Radiation in the Context of a Possible eu Proposal for a Directive on Optical Radiation. National Radiology Protection Board, United Kingdom.
- Patton, J.D., 1983. *Preventive Maintenance: Instrument Society of America*. Publishers Creative Services Inc., New York.

- Premadi, A., B.C. Ng, M.S. Ab-Rahman and K. Jumari, 2010. Access network survivability: An architecture approach for monitoring, protection and restoration in FTTH application. *Ann. Telecommun.*, 65: 263-269.
- Rahman, M.S.A., A.A. Ehsan and S. Shaari, 2006. Self-protected passive optical network using Access Control System (ACS). *Proceeding of the 5th International Conference on Optical Communications and Networks 2nd International Symposium on Advances and Trends in Fiber Optics and Applications, (ICO CN/ATFO'2006)*, Chengdu, China, pp: 335-341.
- Rahman, M.S.A., B.C. Ng and K. Jumari, 2009a. Engineering a network management system for FTTH access network. *J. Applied Sci.*, 9: 2390-2398.
- Rahman, M.S.A., S.A.C. Aziz and K. Jumari, 2009b. Protection for an immediate split structure of tree-based EPON architecture-Ideal condition analysis. *Am. J. Eng. Applied Sci.*, 2: 372-380.
- Rahman, M.S.A, B.C. Nag, R. Ismail, S. Shaari and A.A. Ehsan, 2009c. The implementation of passive in-line monitoring (PIM) device in tree-structured FTTH access network. *J. Optical Commun.*, 31: 91-94.
- Rahman, M.S.A., B.C. Nag, S.A.C. Aziz, M. Tanra, A. Premadi, M.N.M. Saupé and K. Jumari, 2010. High efficiency of FTTH network management through SANTAD. *J. Network Syst. Manage.*, 18: 210-231.
- Rao, S.S., 1992. *Reliability-Based Design*. McGraw-Hill, New York, pp: 1-569.
- Willsky, A.S., 1976. A survey of design methods for failure detection in dynamic systems. *Automatica*, 12: 601-611.
- Yang, S.K. and T.S. Liu, 1998. A petri net approach to early failure detection and isolation for preventive maintenance. *Qual. Reliab. Eng. Int.*, 14: 319-330.
- Yang, S.K., 2003. A condition-based failure-prediction and processing-scheme for preventive maintenance. *IEEE Trans. Reliability*, 52: 373-383.