Visual Basic Software Tool for FTTH Network Management System: SANTAD

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Summary
This paper proposed a fiber-to-the-home (FTTH) network management system named Smart Access Network Testing, Analyzing and Database (SANTAD) for self protected and restored against fiber fault based on Visual Basic. SANTAD is the new upgraded values of recent FTTH technology toward the implementation of smart network, which involved in the centralized monitoring, failure detection, automatic recovery, and increases the survivability and maintainability of FTTH. The functionalities of SANTAD can be generally classified into pre-configured protection and post-fault restoration, consist of network system configuration management, degradation management, fiber fault management, and performance management that support its operations. One suggested in point-to-multipoint (P2PM) applications has been proposed with the experimental results as feasibility approach. This paper also described how the FTTH can reduce the greenhouse gases (GHS) emissions in order to contribute to wider global struggle to ensure our future environment.

Key words:
Centralized monitoring, failure detection, automatic recovery, survivability, maintainability.

1. Introduction

FTTH has played the major role in alleviating the last mile bottleneck for next generation broadband optical access network [1]. A number of factors are increasing the interest among network service providers in offering the triple play services of voice, video, and high-speed data access. Most importantly, subscribers are finding a growing number of applications that drive their desire for higher bandwidth, including Internet access, interactive games, and video delivery.

Since the optical fiber offers a vast amount of bandwidth that can be utilized for communication, one of utilizing this is signal multiplexing. Due to the large bandwidth and the associated high bit rates, the multiplexing process is beyond the capabilities of pure electronic methods and has to be implemented optically as well. As the reach of optical fiber is being extended to the access network it is economically attractive to share fibers between different end-users without adding active components in the network. The optical single mode fiber (SMF) is a very attractive communication medium since it offers a large scale useful bandwidth (25 THz) and low attenuation (0.2 dB/km), therefore it can facilitate demanding services such as high quality video transmission [2].

Fiber network in the telecommunication domain has long been supporting the global International Direct Dialing (IDD) connection. Optical fiber cable is now extending from the underground or ocean to every building and every premise. Broadband connection through fiber is faster and more cost-effective than copper cable and any other means of transmission. Etisalat, Saudi Telecom Co. and Algerie Telecom in the MEA region, France Telecom, Deutsche Telekom and Telefonica in Europe, Korean Telecom in South Korea, NTT in Japan, and AT&T in the United States, are some of the leading operators heading up the promotion of fiber networks in the residential and enterprise markets. Korea, Japan, and Hong Kong are ranking as the top three economies in FTTH penetration on the planet [3].

The first serious interest in FTTH began in the late 1980s as the telephone companies gained experience with Integrated Services Digital Network (ISDN) wideband services to subscribers [4]. Today, FTTH has been recognized as the ultimate solution for providing various communications and multimedia services, including carrier-class telephony, high-speed Internet access, digital cable television (CATV), and interactive two-way video-based services to the end users [5].

FTTH will soon become fiber-to-every-home (FTEH) and fiber-to-the-office (FTTO) will also become fiber-to-every-office (FTEO) as standard for new construction in many developed countries by 2010. Aspen Optics, which has made this prediction, will be speeding up expansion in international markets to hasten FTEH. FTTH will become a distant memory when change to FTEH, with FTTO making the transition to FTEO. The worldwide trend to develop infrastructure around the FTEH statement becomes ever more apparent [6]. The governments of Singapore and Australia are active in funding the deployment (construction) of fiber and infrastructure

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upgrades to expand optical networks. Vienna in Austria had already planned for FTTH since 2005. Amsterdam is another city aiming for FTEH [3]. Staying on European soil, France already has millions of households possessing a fiber connection. The demand of high speed broadband will continue to increase, with worldwide users requiring a high speed service [6].

The increasing demand for high speed broadband in commercial, industrial, medical applications is pushing the use of fiber instead of copper to support mission critical network connection. The phasing out of analog television (TV) to be replaced by Internet Protocol television (IPTV) and the popularity of high definition television (HDTV) is a key factor to make FTEH a necessary reality. In America, analog TV will soon be a thing of the past: the Congress has approved that all TV broadcasters must put an end to analog mode by February 2009 and stick to the digital transmission they have been phasing in already for years [3]. Besides, many countries are considering introduction of digital TV within a few years. As digital TV is very efficient in frequency spectrum utilization, it does not require as much frequency spectrum as analog TV [7].

2. Impact of FTTH on Climate Change

Rapid urban development contributes to man-made climate change and environmental degradation through warmer temperatures. Climate change represents a threat to mankind on a similar level to violet conflict and war and indeed can lead to a breakdown of peace because of the increased competition for the Earth's resources [8]. There are a number of different causes of climate change, many of which are naturally generated (e.g., variations in solar radiation and volcanic activity). However, it is man-made climate change that is a major concern because it appears to be leading to progressive and accelerating warming of the planet, as a result of the release of GHS, primarily carbon-based emissions, including carbon dioxide (CO_2) and methane. Global GHG emissions have risen by 70% since 1970. As a consequence, global average temperatures have risen by around half a degree centigrade from 14^{o}C to 14.5^{o}C since 1950, and there has been a rise in sea level of around 10 cm and reduction of northern hemisphere snow cover of around 2 million km^2 over the same period. Since a measurement began, 11 of the warmest annual average temperatures recorded have been in the last 12 years [9].

The primary sources of GHG are energy production and consumption, transport, buildings, and waste management. Other industries, including Information Communication and Technologies (ICTs) sector, generate around 4% of total GHG, but are much higher (around 14%) if indirect energy used is included. ICTs are a significant cause of global warming. It is estimated that ICTs itself (excluding the broadcasting sector) contributed approximately 6-10% of the world's energy and 2% of global GHS emissions at just under 1 gigatonne of carbon dioxide equivalent ($GtCO_2eq$). The main constituents (about 40%) of the energy requirement of personal computers (PCs) and monitors, with data centers contributing a further 23%. Fixed and mobile telecommunication contribute an estimated 24% of the total [8], while the balance of the output comes from businesses, network operators, and application providers. Although the overall emissions of ICT are relatively small compared to other industry sectors, they are probably fastest growing sector in terms of CO_2 emissions. If something is not done soon, the ICT industry within a couple of decades could be one of the larger industry sources of GHG emissions. These percentages are likely to grow as ICTs become more widely available [10].

The ICT industry is unique amongst industry sectors in that GHG emissions are not a direct outcome of its deployment and use as opposed to transportation, heating, power generation and other industrial processes. The ICT industry contribution to GHG is indirect through the electrical power produced for the electricity to power the electronic equipment and keep it cool. As almost every watt consumed by electronics results in heat an almost equal or greater amount of electricity is required for cooling ICT equipment [10].

The major contribution of ICTs to climate changes from the proliferation of user services, all of which need power and radiate heat. In addition to the proliferation of users, each individual user may now own many more devices. As the ICTs devices acquire more processing power, their requirements for power and cooling also rise. Part of the concern over the global warming effect of ICTs comes from the seemingly inexorable rise in the power requirements of ICT devices driven by the high transmission capacity. ICTs can be major linchpin in efforts to combat climate change and serve as a potent cross-cutting tool to limit and ultimately reduce GHG emissions across economic and social sectors [8].

Climate change could cause more severe floods and drought brings adverse health effects. Climate change alters the incidence and geographical range of malaria and largely confined to urban areas. Effective long-term measures to prevent or mitigate climate change heath effects require a multi disciplinary approach and collaboration with other agencies. It is essential to see that adequate weight is given to health impacts due to climate change.

The key to combating global warming is to stabilize and eventually reduce the emissions of GHG. International success has been achieved with a reduction in ozone depleting substances (e.g., chlorofluorocarbon (CFC) gases) to 20% of their 1990 levels by 2004. However, the CO_2 emissions have grown by around 80% since 1970. Growth in CO_2 emissions outsides Annex 1 countries (developed countries and economies in transition) such as China and India industrialize their economies rapidly. Reducing emissions will require changes in lifestyle and behavior. Part of the concern over the global warming effect of ICTs comes from the power requirements of ICT devices, driven by the high transmission capacity. The transmission capacity of different generations of access network is doubling approximately every year. All things being equal, as transmission capacity rises, so too will power consumption for both devices and networks [8].

To reduce the power requirement for continuing with the broadband access technology, FTTH is one of the examples that provided a reduction in CO_2 emissions [8]. A study conducted by FTTH Council Europe and Price Waterhouse Coopers finds that the first 15 years of a given network implementation, with a reduction in GHG emissions equivalent to 330 kg/user or a car travelling 2000 km. For the other 15 years beyond, the savings are 780 kg/user or a car travelling 4650 km due to the fact that the network is depreciated and only part of the infrastructure needs to be renewed. If further physical barriers are reduced (ducts access in particular) and a full range of services are developing, the contributions will be far bigger [11].

Although ICTs account for only around 2% of total GHG emissions, but they have the capacity to be used in reducing the other 98% in others 98% in other sectors of the economy, notably in smart buildings, reduce travel, and improved energy efficiency. They can do this primarily by creating opportunities for the abatement (or displacement) of existing that generate CO_2. Probably the most obvious area for carbon abatement opportunities offered by ICTs is in is in reducing or subtitling for travel requirements of people and goods. The ICT industry offers a number of different tools and services that can theoretically replace travel, especially business travel, which range from the mundane (e.g., email, phone calls, text, or messaging) to sophisticated (high performance video conferencing) [10].

3. FTTH Network System - SANTAD

SANTAD is a centralized access control and surveillance system that enhances the network service providers with a means of viewing traffic flow and detecting any breakdown as well as other circumstance which may require taking some appropriate action with the graphical user interface (GUI) processing capabilities of Visual Basic software.

The functionalities of SANTAD can be generally classified into pre-configured protection and post-fault restoration, which can be broken down into four broad categories: (i) Network system configuration management, (ii) Degradation management, (iii) Fiber fault management, and (iv) Performance management. SANTAD can help network services providers and field engineers to perform the following the following activities in FTTH network system:

- Monitors and controls the network performance
- Detects degradations before a fiber fault occurs for preventive maintenance
- Detects any fiber fault that occurs in the network system and troubleshoots it for post-fault maintenance.
- Provides the network service providers with a control function to intercom all subscribers with CO

A remotely control and monitoring platform has installed at CO to provide:

- Communication between CO and point of link control (remote site)
- Communication between CO and end users (customer premises/subscribers)
- Further processing of controlling/monitoring information for preventive maintenance
- Presentation of surveillance image (visual feedback)
- Events/data recording

3.1 Network System Configuration Management

Network system configuration management provides the network service providers with a control function to intercom all subscribers with CO. The network system configuration knows all the hardware in network system (including the deployment, connection, splice, fibers joint, optical device, component, and optical fiber line), the status of each entity, and its relation to other entities. This alerts the network services providers to determine the path used by the services through the network in working (ideal/good) condition and non-working (failure/breakdown) condition.

3.2 Degradation Management

Degradation management tries to prevent fiber fault from occurring. Although this is not always possible, however some types of failure can be predicted and prevented. SANTAD can tracks small changes based on the optical signal level (input/output power) and losses (connection losses, splice losses, optical device/component losses, fiber losses or attenuation) at each point for the preventive maintenance purposes. By in-service monitoring with SANTAD, the field engineers can view the service delivery and detecting any circumstances which may require some promptly action before it turns into big trouble and causes a tremendous financial loss.

3.3 Fiber Fault Management

Fiber fault management involves the fiber fault detection, notification, verification, restoration functions, and documentation (recording fiber fault). Fiber fault prevention is aims to prevent fiber fault from happening. Even with fiber fault prevention mechanisms, failures will still occur, so fiber fault detection techniques need to test each optical line in order to detect potential faults and precisely localize the exact failure location. With detected alarms, fiber fault identification processes will diagnose and determine the real causes. Appropriate recovery actions are taken to treats the link and fiber fault.

The first step taken by the fiber fault management system is to detect any fiber fault occurs in a faulty line and the exact failure location. Once any fiber fault in the primary entity is detected, it will automatically send the failure status to the field engineers through wireless technology. The overall block diagram representing the failure notification between CO and field engineers is shown in Fig. 5. The image (simulation result) captured by remote PC (at CO) will be stored as .jpeg format file with resolution of 1024x768 and will compress to 640x480 before transferred to personal digital assistance (PDA) (with field engineers) via WiFi 802.11g using file transfer protocol (FTP). The image can be send to the field engineers in average radius of 50 m from the wireless router less than 1 second with transfer rate 20-30 Mbps (the theoretical maximum bandwidth is up to 54 Mbps).

The field engineers can determine sharply the break point just connect a laptop or PDA to the optical time domain reflectometer (OTDR) test module through Ethernet connection without making a site visit before taking some appropriate actions, such as repairing or maintenance operation. Meanwhile, the field engineer will activate the restoration scheme to switch the traffic (service delivery) from the failure (primary) line to the protection (backup) line to ensure the traffic flow continuously. This functionality alerts the network service providers and field engineers of a fiber fault before it is reported by the customer premises or subscribers.

After the restoration/maintenance process, the traffic will be switched back to the normal operation. The detail of the fiber fault must be documentation. The record should show the faulty fiber, exact failure location, possible cause (i.e. construction is conducted in the nearby areas), action taken, cost, and time it took for each step. The documentation is extremely important for several reasons:

- The problem may recur. Documentation can help the present or future field engineers or technicians solve a similar problem.
- The frequency of the same kind of failure is an indication of a major problem in the system. If a fault with a similar one, or the whole network system should be changed to avoid the use of that type of fiber/device/component.
- The statistic is helpful to another parts of network management [12].

3.4 Performance Management

Performance management is closely related to degradation management and fiber fault management, tries to monitor and control the network to ensure that it is running as efficiency as possible. SANTAD stores the real time, daily, weekly, monthly, quarterly, and yearly analysis results in database for further processing and queries. All kinds of additional information can be easily accessed and queried later. The database system enables the history of happens frequently in one fiber/device/component at the same location (same point), it should be replaced network scanning process be analyzed and studied by the field engineers.

The network service providers and field engineers can first establish the relationship between network failure rate and network performance based on measurements and statistics. The relationship between network failure rate and network performance can be monitored by SANTAD 24 hours a day and 7 days a week. The field engineers can evaluate the network performance via summarized the each network performance plot, which may require some promptly action.

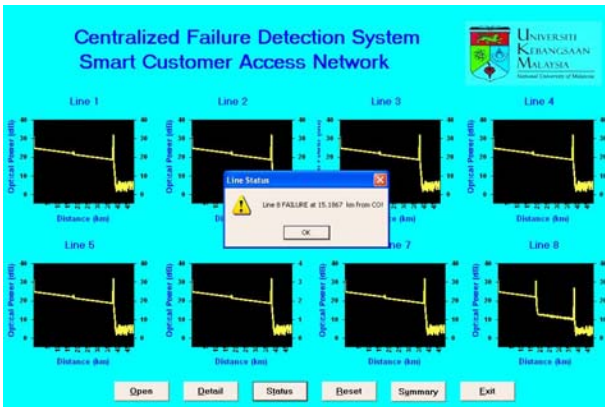

Fig. 1 Accumulated every 8 measurements for centralized monitoring in *Line's Status* form.

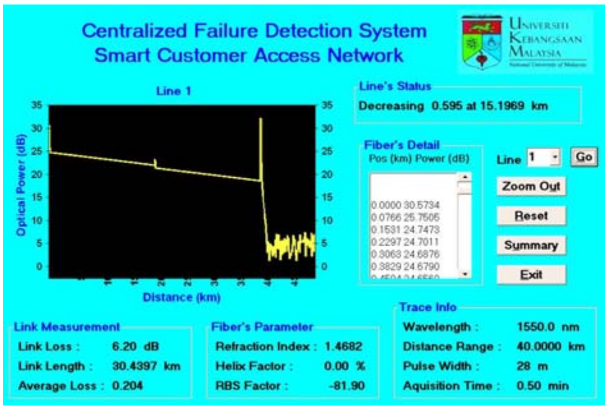

Fig. 2 An example of working line in the *Line's Detail* form.

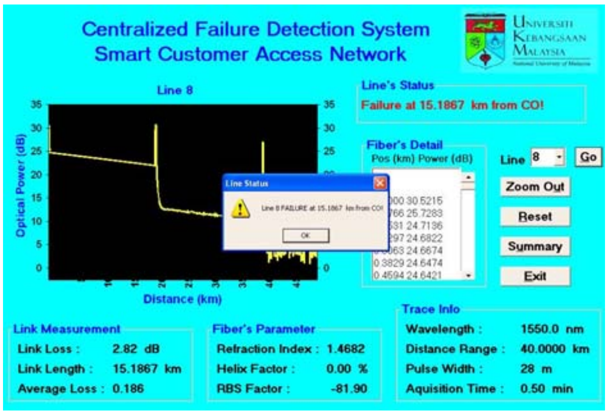

Fig. 3 An example of non-working line in the *Line's Detail* form.

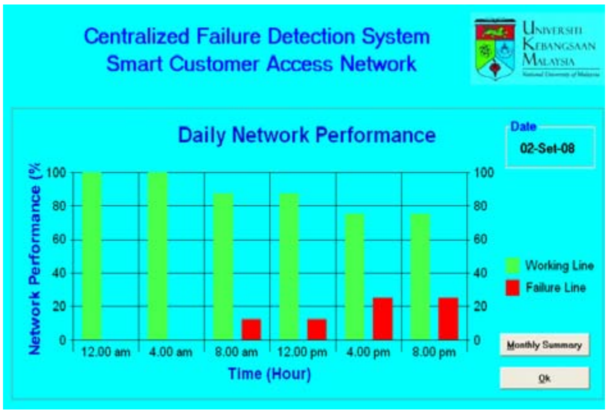

Fig. 4 Analysis of the relationship between network failure rate and network performance.

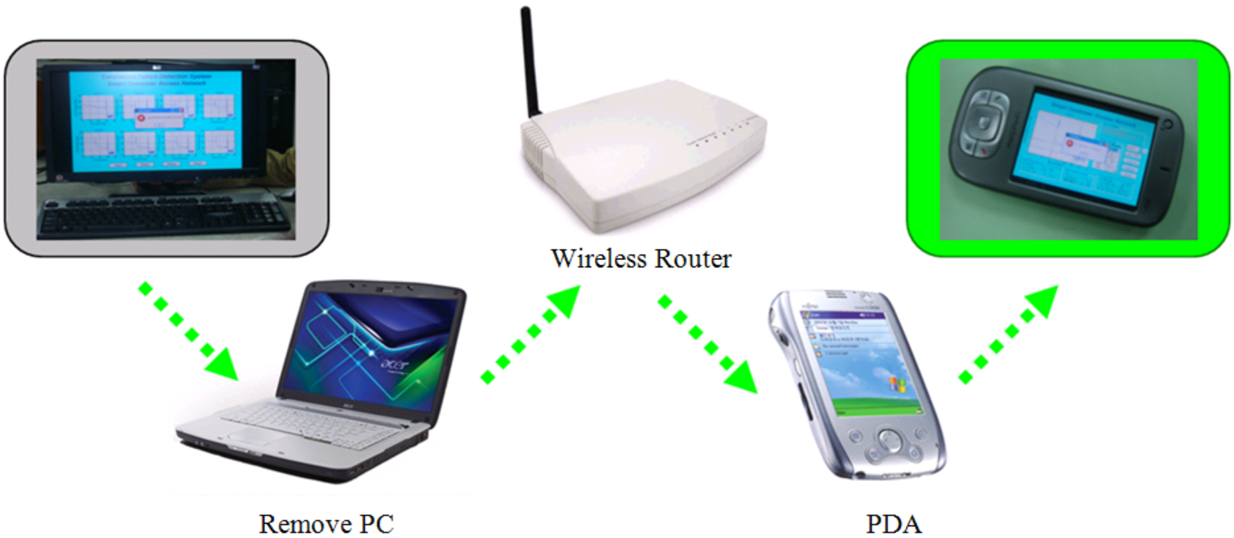

Fig. 5 The image captured by remote PC will be stored as .jpeg format file and then transferred to PDA via WiFi

In combination of the distinctive management operations, the network service providers and field engineers can centralize monitoring, testing, analyzing, configuring, and troubleshooting the FTTH network system more efficiency to provide the predefined quality of services (QoS) for customer premises/subscribers.

3.5 Future Enhancement

All of these four management operations are the first report up to this point of time. In the future, we aim to add another three management operations, (i) Users accounting management, (ii) Identification management, and (iii) Security management into SANTAD.

- Users accounting management - verifies a given subscriber is permitted to access a given service controls the users for accessing to the network resources through charges.
- Identification management - determines whether an identified entity or element of the content and prevents tracking by an unauthorized person.
- Security management - controls the users for accessing to the network resources through predefined policy.

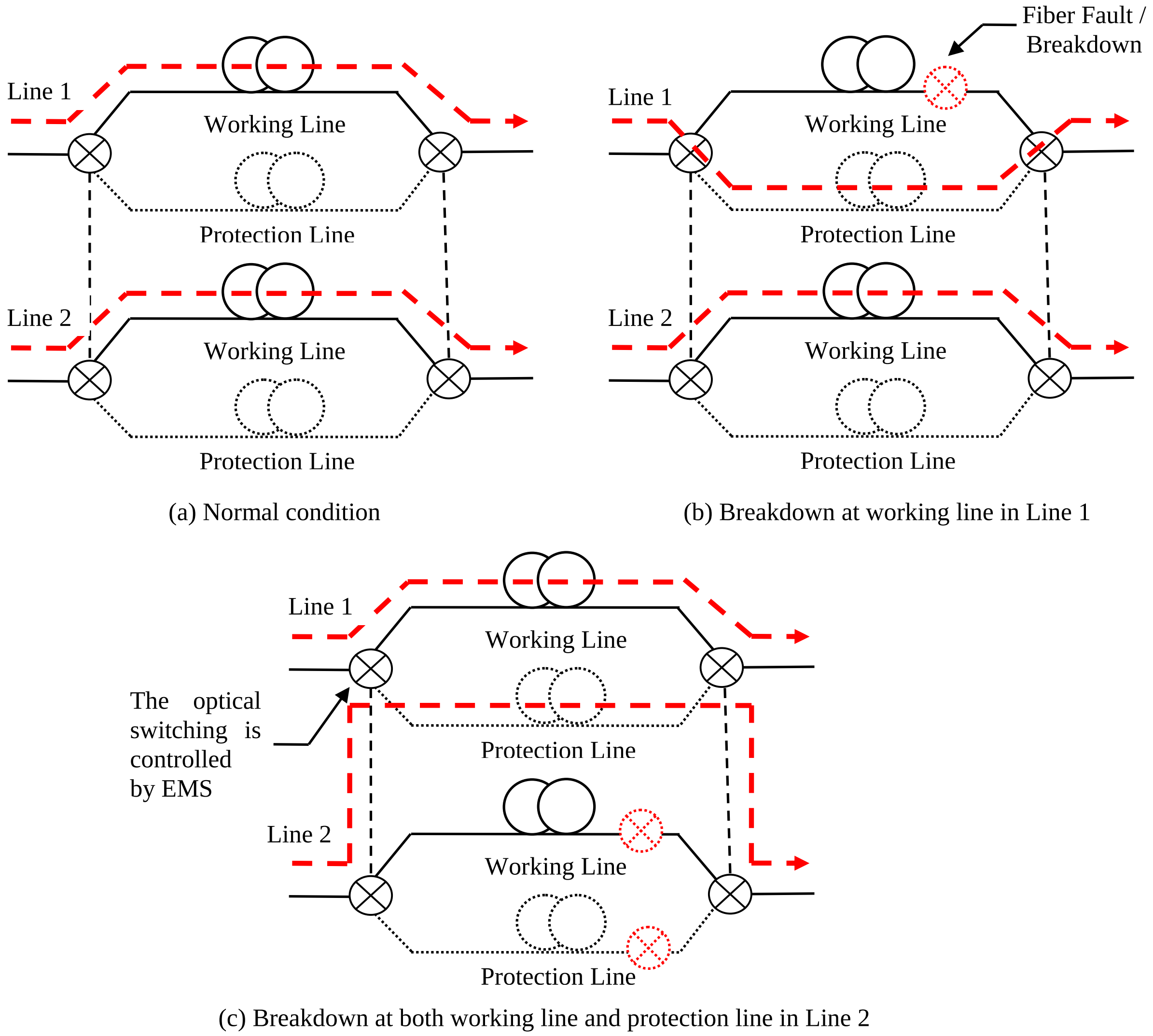

Fig. 6. Mechanisms of protection in FTTH in failure condition.

4. Failure Link Recovery and Optical Switching

Link failures are the most common and occur when a fiber cable is accidentally cut when digging in an area through which fiber cables pass. Protection can be performed at the level of an individual light path or at the level of a single fiber. Path protection denotes schemes for the restoration of a light path, and link protection denotes schemes for the restoration of a single fiber [13]. In our design, the link protection is done in a non-dedicated 1:1 manner; there are two fiber lines, a working line for bi-directional connection and another reserved as a protection line (Stand-by/backup line). The signal is transmitted over the working line. If it fails, then the source and destination both switch to the protection line.

Traffic engineering is a key technology to guarantee the QoS in large scale backbone network. A microprocessor system is used to control the optical switch for switching the working traffics 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. Two optical switches are allocated in each transmission line in feeder region (from OLT to optical splitter) and drop region (from optical splitter to ONU). The first optical switch is used to switch the signal to protection line at local or nearby transmission line, while the second optical switch will switch the signal back to the original path after bypass the failure point.

Fig. 6 shows the mechanisms of protection in FTTH in normal condition and failure condition. During normal operation, the optical signals are transmitted over the working line (see Fig. 6a). If the working line fails, the source and destination both switch to protection line to ensure the traffic transmitted simultaneously in the network system. Fig. 6b shows the simplified schematic of an example of an FTTH with a self-protection and restoration to allow the optical switching in case of fiber cut. Since there is one protection line, only one working line can be protected at any time. It is also possible that the working line and protection line might get cut at the same time. In this case, the traffic will be switched to the protection line from neighborhood as shown in Fig. 6c. Once the failure line has been repaired, the optical signals will be automatically switched back from the protection line to working line.

5. Conclusions

A new approach of using Operation, Administration, and Maintenance (OAM) features to monitoring the network system status and detect any fiber fault that occurs in FTTH has been proposed and validated with experimental results. The proposed FTTH network management system (SANTAD) accumulated all the measurement results from OTDR into a PC screen and accurately determined the faulty fiber as well as the failure location in the network system using event identification method. It is a cost-effective way to detect any failure occurs within FTTH to improve the service reliability and reduce the restoration time and maintenance cost.

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