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The Eye Diagram Analysis of Restoration Scheme in FTTH-PON

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Abstract: In this study, a technique for automatic restoration scheme for the ease of customers in a passive optical network is proposed. Protection switching against the failure in fiber line is carried out using our restoration scheme. The smart and intelligent system of FTTH is expected to be a key element which provides centralized monitoring, survivability and instantly maintenance of FTTH customer access network. In this study, we implement a cost effective restoration scheme for a novel tree-based for Intermediate Split Structure (ISS) in the drop region section. The protection mechanism for tree based optical switch will have capability to divert the signal onto protection line according to the types of failure condition and location of failures in access network by means of Zig Zag mechanism. This will ensure the data flow continuously due to breakdown occur in the network and instantly repair operation. We employ the dedicated and shared protection in our design. Four faulty conditions are considered in this article and OptiSystem, Inc. software is used to prove the solution feasibility. This study focused on the eye diagram parameter analysis in the FTTH-PON network during the working and failure condition. Four parameters will be concentrated which are BER, eye opening, maximum Q factor and jitter. In the case of failure condition, four restoration schemes are activated to ensure the signal flow continuously without perturbation.

Key words: Intelligent system, passive optical network, divert, breakdown protection, restoration scheme

INTRODUCTION

Ethernet technologies have contributed to the lowering the cost of FTTH network implementation. Application of the Ethernet standard has expanded from the enterprise LAN to the access network environment. However, the application of Ethernet technologies to the access network systems is still at an intermediate stage of development (Fujimoto, 2006). In order to support the services applications a number of network technologies are proposed, each with advantages and drawbacks. Before going to transport solutions in the access market it must noted that the actual transporting is done by a bandwidth, which refer to not only the quantity of data it can carry, but the speed at which the signal travel; bandwidth is measured in megabits or gigabits per second. In a point to multi point (P2MP) PON, the downstream 1490 nm wavelength and upstream 1310 nm wavelength are used to transmit data and voice. The downstream wavelength 1550 nm can be used for analog video overlay. Multiple Optical Network Termination (ONT) are connected through one or more optical splitters. In a point to point (P2P) system, the voice and data are transmitted on the same wavelength downstream and upstream because it uses a fiber pair; one fiber downstream and another one upstream. Because the downstream power is divided among the ONTs by the splitter, FTTH P2MP PONs have considerable optical loss. In order to ensure that each branch of the P2MP PON will operate correctly and meet all specification, the network it must be establish optical power budget. The loss budget specifies the minimum and maximum amount of loss margin that can be tolerated in between the OLT and ONU.

Passive Optical Networks (PON) is a point-to multipoint optical network with no active elements in the signals path from source to destination. Figure 1 shows the FTTH PON basic architecture. The only interior elements used in such networks are passive combiners, couplers and splitters (Yeh *et al*., 2008). In order to share the available total bandwidth, a bidirectional 1×N splitter is used in a P2MP PON. The splitter is a bidirectional broadband branching device that has one input port and multiple output ports. The input optical signal is divided

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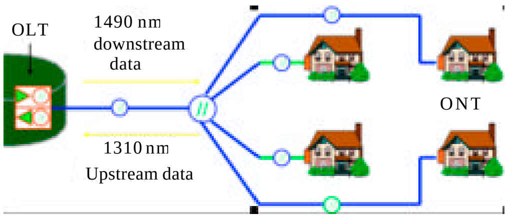


Fig. 1: FTTH-PON which used the Intermediate Split Structure (ISS) architecture

among the output ports, allowing multiple users to share a single optical fiber and consequently share the available bandwidth of that fiber. In the upstream direction, optical signals from a number of ONTs are combined into the single fiber. In the upstream direction, data frames from any ONU will only reach the OLT, not another ONUs due to directional properties of a passive combiner such as optical splitter. In this case, in the upstream the behavior of EPON is similar to that P2P architecture (Kramer and Pesavento, 2002). The passive coupler is positioned not more than 1 km from residential customers, in order to minimize fiber usage. Each customer receives a dedicated short optical fiber but shares the long distribution trunk fiber (Png *et al*., 2005).

A typical EPON architecture is composed of one Optical Line Termination (OLT) and Multiple Optical Network Unit (ONU) connected to the OLT via a passive optical splitter (Chen *et al*., 2004). EPON vendors are focusing initially on developing Fiber To The Business (FTTB) and Fiber To The Curb (FTTC) solution, with the long term objective of realizing a full service Fiber To The Home (FTTH) solution for delivering data, video and voice over a single platform (Vacca, 2007).

EYE DIAGRAM PARAMETER

This study focused on the eye diagram parameter analysis in the FTTH-PON network during the working and failure condition. Four parameters will be concentrated which are BER, eye opening, maximum Q factor and jitter. In the case of failure condition, four restoration schemes are activated to ensure the signal flow continuously without perturbation. In this research, the eye diagram that shown in Fig. 2 is used to analyse the working and failure condition in the FTTH-PON network. The analysis is done based on four parameters in order to determine the quality of received signal. The parameters are Eye height, Maximum Q Factor, Jitter and Eye area.

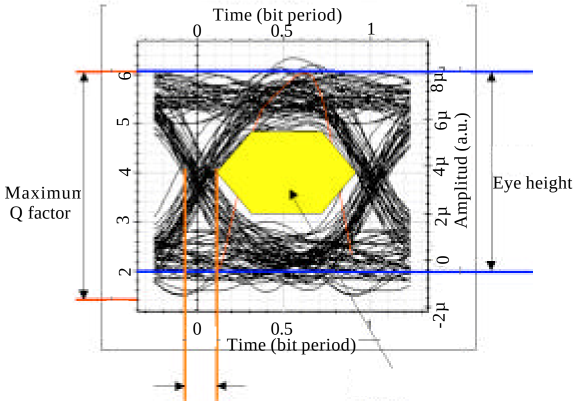


Fig. 2: Eye diagram parameters which determine the quality of receive signal

Eye height: It refers to the distance from the base to the peak of the eye measured in voltage. The allowed minimum height value of the eye diagram is inversely proportional to the photosensitive sensitivity. High photosensitive sensitivity could assess data at low height value of eye diagram whereas low photosensitive sensitivity requires high eye diagram height value for data assessment (for example, at photosensitive sensitivity-22.8 dBm, the eye diagram height value is 5.5 µV and at sensitivity-18 dBm, the allowable eye diagram height value is 10 µV). If there is any fixation on the photosensitive sensitivity value, the increase in data transmission rate will give similar eye diagram height value.

Maximum Q factor: The maximum Q factor refers to the quality of the produced eye diagram to be analyzed. This value is fix and equal for all photosensitivity values for various data transmission rate. The allowable maximum Q factor is 6 in current communication system to obtain BER value equivalent to 1×10^{-9}.

Jitter: Deterministic jitter refers to the shifting which occurs on derivative and embedded time of the received signal and the value is measured according to the duration at the crossing point. It is measured in UI (unit interval) unit and the allowable maximum value is 0.2 UI. Normally the jitters are generated and give pronounce impact on the data transmission system of more than 1 Gbps.

Eye area: Eye area refers to the distance between levels of bit 0 and bit 1 and the distance between right and left embedded derivatives time crossing. The parameters are applied in mask technique to evaluate the quality of the received signal. The width of this area is important in the process of differentiating bit 1 and bit 0 as well as the sequence of the first and second bits. The more wide the eye areas is, the bigger the received data quality is and thus, the process of signal sampling becomes easier.

OVERVIEW OF PROPOSED RESTORATION SCHEME FTTH-EPON

In this study, we concentrated on four types of failure mechanism. For every type of protection mechanism, we employ the dedicated protection and shared protection. If traffic prioritization is implemented, high priority traffic is transmitted on the primary path whereas the best effort traffic is diffused on the backup path. In case the primary path breaks, the high priority traffic is transferred to the backup path. The failure protection and recovery of services needs the following actions: When the breakdown occurs, then it must be detected and the information about the failure has to be propagated to the nodes triggering protection switching actions. For switching the service from a failed working path to a backup path, then the backup path has to be set up. Thus, a suitable route with sufficient resources has to be found for the backup path means that a pre-established backup path has to be disjointing from the working path. Resources need to be allocated to the backup path. Finally, the service has to be switched over to the backup path. The described actions may take place at different points in time.

For dedicated path protection, a working path and an end to end backup path is established and resources are assigned to it at connection set up time. There is a difference between 1:1 and 1+1 protection. In 1+1 protection, the client signal is transported simultaneously on both working path and backup-path, whereas in 1:1 protection, the client signal is switched over from the working to the backup path after the occurrence of a failure. In this case, the backup resources can be used for pre-emptive services in the absence of a failure on the working path.

However, from a resource perspective, both mechanisms are the same. Hence, we will not make a distinction between the two mechanisms and refer to them as dedicated path protection. In our case study we assume the working path to be link disjoint from the backup path which ensures to protect against any single link failure. In shared protection, backup paths are pie-calculated and sufficient backup resources are preplanned. However, backup paths are assigned to specific protection paths only after a failure occurrence. Sufficient in this context means that the backup resources are dimensioned so that service recovery from any single link failure is guaranteed. Many different ways of sharing resources and many approaches for dimensioning and optimizing the shared backup resources are possible. It is unrealistic to plan and optimize the backup resources for all services of a dynamic network in a common step, but it has to be done sequentially at service request by service request. We establish the working path on the shortest available route, and calculate a link-disjoint backup path, which reuses as much backup resources of previously established services as possible. Only those backup resources of other services are used which are not subject to the link failures on the established working path. As needed, additional backup capacity is reserved. The concept provides 100% protection guarantee in case of single link failures. The nodes compute the working and the backup path based on information about whether a wavelength on a link is used as backup or working resource, or whether it is free. Using this method, little additional backup resources are assigned.

Working condition A: In Fig. 3, the grey arrow shows the normal network condition when there is no failure occurs in the working line. As the working line is in a good condition, the optical signal could be sent through it and the protection line is not being used.

Failure condition B: Figure 4 shows the failure is detected in working line, protection mechanism will be activated and convert the optic signal direction to the protection line. The arrow shows the protection mechanism as dedicated protection.

Condition failure C: Figure 5 shows the shared protection scheme when breakdown occurs in both line in working line and protection line. Shared protection scheme will be activated and optic signal will convert the route to neighbor line protection as depicted with black arrow.

Condition failure D: Figure 6 shows the breakdown occurs in both lines and shared protection scheme will be activated and the signal will be routed to the next neighbour protection line. However when the failure also occurs in the neighbour working line, then the mechanism design protocol will give priority for dedicated protection and the signal will be routed to the next neighbour line protection which is in normal condition as in light grey arrow. The dark grey arrow represent the protection mechanism which convert the optic signal to the second neighbour protection line as the first neighbour protection used for dedicated protection (black arrow).

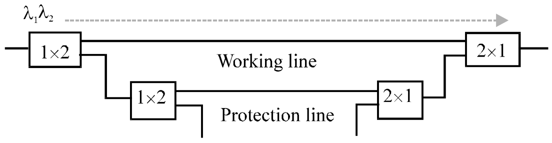


Fig. 3: Protection mechanisms in ideal condition

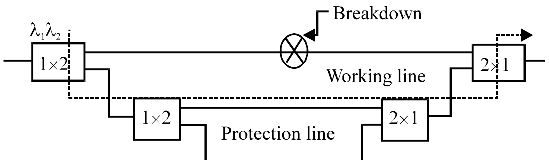


Fig. 4: Breakdown occurred at working line and signal is diverted to the protection line

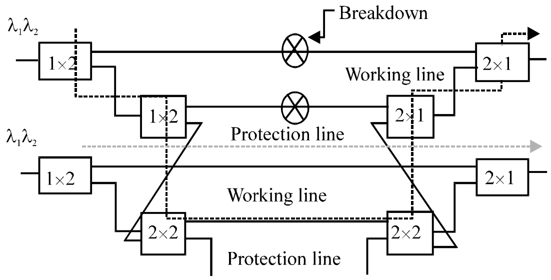


Fig. 5: Breakdown occurred at working line and protection line. Signal is diverted to the neighbour protection line

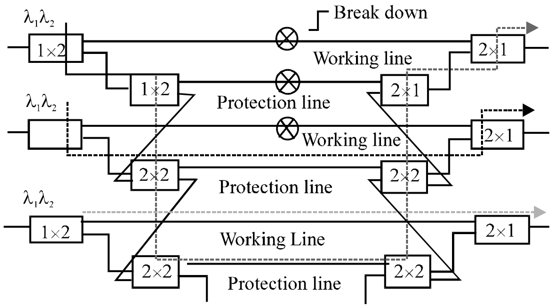


Fig. 6: Breakdown occurred at working line, protection line and working line neighbour

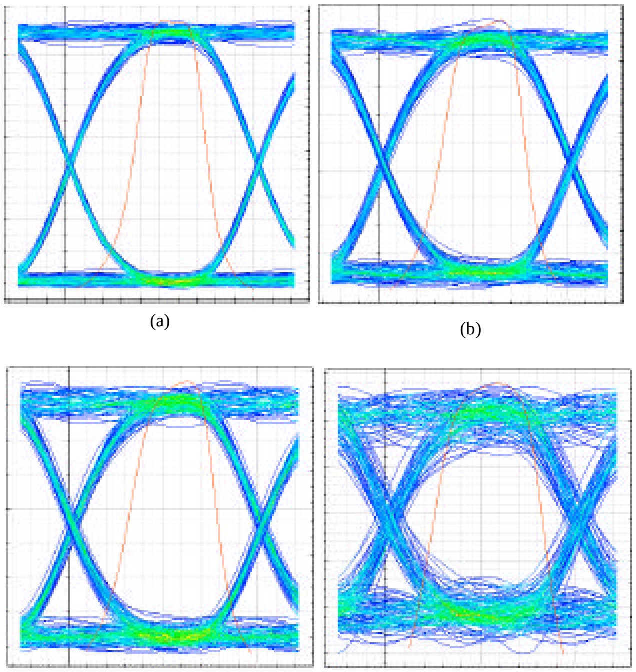
RESULTS AND DISCUSSION

The FTTH based network design was modeled and simulated using the Optisystem CAD program by Optiwave System, Inc. The two optical fibers were connected between the transmitter and 1:8 bidirectional splitter (18 km) using a bidirectional optical fiber also the other one was linked between splitter and ONUs (2 km) by using Single Mode Fiber (SMF). In the downstream direction, at the OLT, two wavelength channels which are 1550 and 1480 nm are multiplexed and transmitted in optical fiber (18 km) to the bidirectional splitter. In the upstream direction the 1310 nm wavelength was transmitted. Simulation aims to verify the network system feasibility and investigate the system performance of the proposed protection route mechanism based EPON architecture. In this simulation we proposed FTTH-EPON design will have 8 ONUs. A transmission distance between OLT and ONU is 20 km. The 1480 and 1550 nm downstream signals and 1310 nm upstream signal have 1.25 Gb sec^{-1} direct modulation in the test access network. And the output powers of 1480 and 1310 nm lasers are 0 dBm. Moreover, the power budget of the architecture as follows. In normal condition, 1480 and 1550 nm signals will traverse one circulator bidirectional (1dB), bidirectional optical splitter (3dB) and about 20 km Single Mode Fiber (SMF) (5 dB), one multiplexer (0.5 dB), one demultiplexer (0.5 dB) and two numbers of optical switch (2.4dB) thus, the total loss budget is about 12.4 dB. The sensitivity of optical receiver, which is used in our test system, is nearly to -34 dBm. The Bit Error Rate (BER) performances are measured by a 1.25 Gb sec^{-1} Non-Return-to-Zero (NRZ) Pseudo Random Binary Sequence (PRBS) with a pattern length of 2^{31}-1 for the downstream traffic between the OLT and 8 ONUs. The specifications of components in this simulation model are tabulated in Table 1. Our results were obtained by observing bit error rates, eye diagrams, optical power levels and dispersion levels.

Table 1: Simulation parameters

	Condition			
Component	A	B	C	D
Transmitted power (dBm)	0	0	0	0
PBRS generator (Gbps)	1.25	1.25	1.25	1.25
Demultiplexer loss (dB)	0.5	0.5	0.5	0.5
Multiplexer loss (dB)	0.5	0.5	0.5	0.5
Bidirectional splitter (1:8) Loss (dB)	3	3	3	3
Circulator bidirectional (dB)	2	2	2	2
Bidirectional optical fiber loss (dB)	0.25×20	0.25×20	0.25×20	0.25×20
Optical Switch loss (dB)	1.2×2	1.2×4	1.2×6	1.2×8
Loss (dB)	25.8	28.2	28.9	32.5

Eye diagrams show parametric information about the signal which is the effects deriving from physics such as system bandwidth health. It will not show protocol or logical problems. If a logic 1 is healthy on the eye, this does not reveal the fact that the system meant to send a zero. However, if the physics of the system mean that a logic one becomes so distorted while passing through the system that the receiver at the far end mistakes it for a zero, this should be shown in a good eye diagram.



(a) (b)

(c) (d)

Fig. 7: Observed eye diagrams for (a) 1550 nm downstream at working condition A, (b) 1550 nm downstream at condition failure B, (c) 1550 nm wavelength at condition failure C and (d) 1550 nm wavelength at condition failure D

Table 2: Signal parameter from the eye diagram

Condition types	Analysis	Wavelength (1550 nm)
Condition A (received power-25.8 dBm)	Jitter	0.0409935
	Eye opening	5.21E-06
	BER	1.00E-258
	Q Factor	34.3021
Condition B (received power-28.2 dBm)	Jitter	0.0559126
	Eye opening	2.82E-06
	BER	1.00E-97
	Q Factor	20.8805
Condition C (received power-28.9 dBm)	Jitter	0.0561559
	Eye opening	2.32E-68
	BER	1.00E-06
	Q Factor	28.9
Condition D (received power-32.5 dBm)	Jitter	0.120794
	Eye opening	7.50E-07
	BER	1.00E-15
	Q Factor	7.77955

Figure 7 a-d show the eye diagram for downstream wavelength. Clear opening eye diagram were observed for working condition A rather than failure condition D. Failure at condition D gives the highest value of dynamic range since in the failure condition, the protection route mechanism uses eight numbers of optical switches to perform the protection and restoration scheme to the network. The results in the form of eye diagrams from which various signal parameters can be calculated. Table 2 gives the value of calculated parameter such as Q factor, eye opening, jitter and BER value for all condition types. There is a reduction in jitter, eye opening, BER and Q factor for failure condition when it use many protection route to implement the restoration scheme as in condition D.

For every number of optical switch, the insertion loss is considered equal to 1.2 dB. In this simulation, the values can be accepted and above the minimum requirement which is 6 (~ BER = 1×10^{-9}) was achieved. For every type of protection mechanism, we employ the dedicated protection and shared protection. According to the four failure conditions which is condition A, condition B, condition C and condition D the protection route will involve in two, four, six and eight numbers of optical switch, respectively.

Figure 8a and b show the eye diagram for (a) the downstream data at 1.25 Gb $\sec^{-1}$ in -25 dBm sensitivity and (b) -34 dBm sensitivity. From the result achieved, the simulation model was simulated in -25 dbM and-34 dBm sensitivity. Clear opening was observed at-34 dBm sensitivity. The receiver performance is characterized by measuring the BER as a function of the average optical power received. The average optical power corresponding to a BER of 10^{-9} is a measure of receiver sensitivity. By using the optimization in receiver sensitivity, we found that receiver sensitivity managed to be adjusted in -25 dBm sensitivity using goal attainment type of optimization which is commonly used for parameter

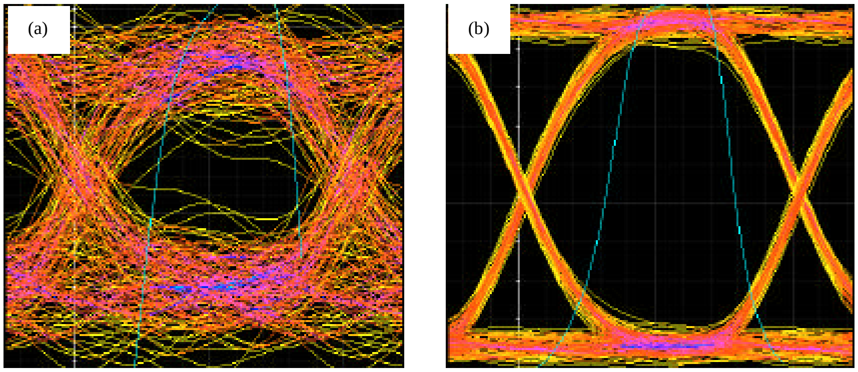


Fig. 8: Eye diagrams observed from 1550 nm wavelength in (a) -25 dBm sensitivity (b) -34 dBm sensitivity

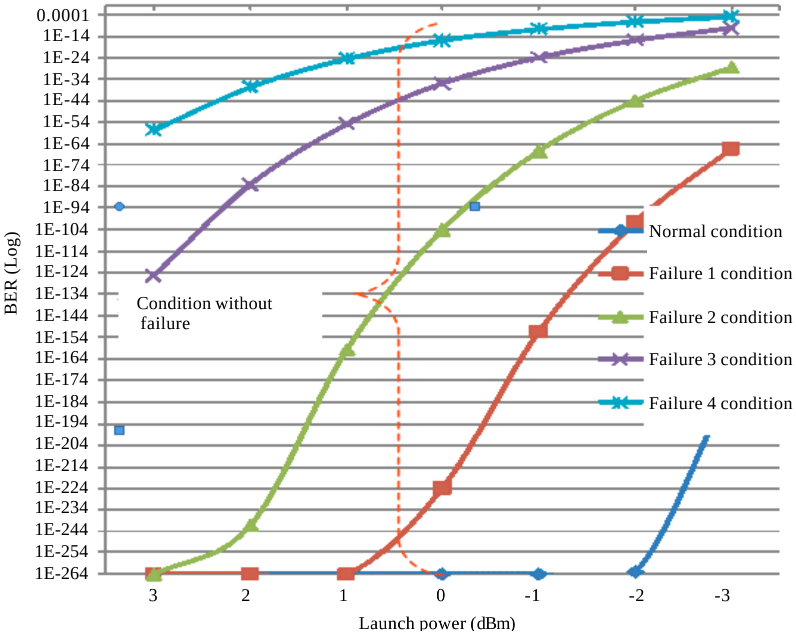


Fig. 9: Effect of BER on the launch of the enhanced up to 3 dBm. BER obtained decreased exponentially when the launch power increases

extraction. Then the thermal noise of a PIN extracted to obtain receiver sensitivity that equal to-25 dBm. For this simulation we set the receiver sensitivity to-34 dBm by using the SPO optimization. From the result achieved, the proposed architecture design in all condition can only been used effectively in-34 dBm sensitivity, since the receiver sensitivity of -25 dBm is not manage to provide good system performance.

In optical receivers, a receiver is said to be more sensitive if it achieves the same performance with less optical power incident on it. The performance criterion for digital receivers is governed by Bit-Error Rate (BER), which is defined as probability of incorrect identification of a bit by the decision circuit of the receiver. A commonly used criterion for digital receivers requires the BER to be below 1×10^{-9} (Max Q Factor ~ 6).

Simulation platform has been built to simulate the performance of each state of failure is available. The objective of this study is to examine the effects of restoration on the activation of the system BER

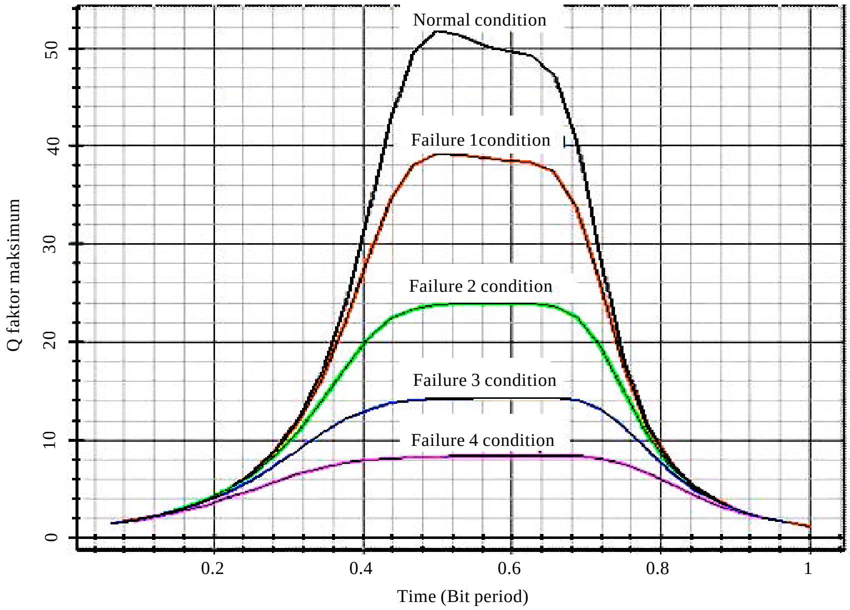


Fig. 10: Q factor values of a time frame for each of the faults in the network

performance. Input power was changed from -3 dBm to 3 dBm and BER observed. Observations made on the BER profile formed on the restoration schemes. It was found that the signal attenuation can be seen clearly when the damage is increasing. The slight narrowing of the signal obtained across the normal state without failure. Figure 9 shows the effect of BER on the launch of the enhanced up to 3 dBm. BER obtained decreased exponentially when the launch power increases. Is possible if the power is reduced to -2 dBm launched on the damage level 4, the bit rate will be increased up to 1e-08. If the signal is too weak, then the data signal will be difficult to separate the noise and causes the error received are increasing.

Figure 10 shows the effect of changing the maximum Q factor with a bit of time in which quality is obtained with a high Q factor in the normal state. The situation has resulted in damage to the four factors that diminished the quality and turn into shrinking the Q factor of 6.4.

The survivability of FTTH network is necessary to provide seamless services and ensure network reliability. Single failure in the line connected will activate the dedicated protection while shared protection is activated when both fiber (working and standby fiber) are breakdown. The BER characteristics were measured at 1.25 Gbps and no degradation was observed, as confirmed by a comparison of these simulation results with those obtained from systems without restoration element. The simulation model and the results were presented to convince proposed protection scheme. Survivability in network system will provide the protection and restoration architectures and it continued services in the presence of failures. The survivability will add redundant capacity, detect faults and automatically re-route traffic around the failure. So the mechanism of restoration for the system was designed to meet the network specification.

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