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Ideal and non Ideal Condition Analysis based on Protection Scheme in Distribution Fiber for Immediate Split Ftth-pon

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Abstract: Fiber-to-the Home (FTTH) network security has become a very essential and important topic for optical network. Fault isolation became important issues in order to provide an efficient FTTH network and simultaneously will provide continuous services to the end user without being interrupted by any failure in fiber line. In this study we discussed about the analysis for restoration scheme proposed in order to proof the system feasibility in our network survivability. Restoration scheme against the failure in distribution fiber line has been proposed. In this study, we implement a protection scheme for a novel tree-based for Intermediate Split Structure (ISS) in the drop region section. The protection mechanism will have capability to divert the signal onto protection line according to the types of failure condition and location of failures in access network. Method of analysis is discussed in two different ways, which are in ideal condition analysis and non-ideal analysis. Under ideal analysis it is involved in simulation approach according to proposed restoration scheme design. The system performance was investigated through the most common test on high-speed digital communications components and system that include the eye diagram, jitter, Q factor and bit error rate measurement. While under the non-ideal analysis it has been discussed about the power penalty analysis for optical switch cascaded in our network protection design according to the types of failure conditions.

Key words: FTTH, ISS, protection scheme, restoration scheme, simulation, analytical

INTRODUCTION

Ethernet based Passive Optical Network (PON) technology is emerging as a viable choice for the next-generation broadband access network (Yeh *et al*., 2008; Png *et al*., 2005). In this study we proposed the restoration architecture that can be applied in FTTH EPON especially in drop region (optical splitter to ONU). Any failure occurs in this region will be switched the traffic to the alternative path according to the types of failure. Failure in single working line will divert the signal to protection fiber that bundled together in one single cable. But if failure occurs on cable (both fiber damage) has to switch the signal to the other alternative protection line of neighbour connection. The first restoration scheme named as linear protection and the latter is shared protection. Both scheme proposals on survivability have aimed on ensuring the traffic flow continuously from OLT to ONU. This can be done by wisely and well-planned on fiber installation during FTTH deployment.

In order to ensure that each branch of the Point to multipoint 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. The only interior elements used in such networks are passive combiners, couplers, and splitters (Png *et al*., 2005). In tree architecture, each ONU is connected to the splitter by a dedicated fiber (Fujimoto, 2006), while in ring architecture all ONUs are connected by a single ring (Kramer and Pesavento, 2002; Hossain *et al*., 2005).

The protection mechanisms must be incorporated in the communication system. In order to eliminate a single point of failure In G.983.1, four protection schemes for the APON interface have been recommended. The protection type A, which is a fiber-duplex system can protect the trunk. The protection type B, which is an OLT only duplex

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system, can protect the OLT. But, the costs are relatively expensive rather than protection type A. The protection type C, which is a full duplex system, and the protection type D, which is a partial duplex configuration, can protect the whole network, but those are too expensive to implement in the actual environment.

From previous proposal, they proposed a protection traffic using multiple flows that carry traffic between a source and destination (Maach *et al*., 2005). An algorithm that identifies for primary traffic and another backup for primary traffic for protection was also proposed.

OVERVIEW OF PROPOSED RESTORATION SCHEME FTTH-EPON

Figure 1 shows the FTTH PON protection architecture in distribution fiber. The working line in distribution fiber will be protected by duplicating the working line to the protection line. This type of protection will effectively used when the optical switch automatically diverted the optic signal to the protection line fiber in presence of failure. Optical switches allow to re-route traffic in spare fiber line in case of failures. The implementation of customer placed device was discussed in order to provide the protection scheme in optical networks as well as providing continuous services flow at the end user side (Rahman *et al*., 2009). Protection scheme will reroute the traffic on spare fiber line resources that have been provisioned for a pre-determined set of failures. Furthermore, the optical signals can be protected and restored by diverting the traffics line up to third number of failure orders in sequence line. In our network protection design, we proposed a centralized restoration when the application of restoration routes is done in a centralized network controller, where all necessary and up to date line status is needed. The discussion and implementations towards controller system was discussed by Rahman *et al.* (2008).

We employ the dedicated protection and shared protection in our protection scheme. 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 which is a controller system (Rahman *et al*., 2008). The controller system will then recognize the related access line by the 3% tapped signal that is connected to every access line. All of these operations are performed in Ethernet domain. The activation signal is then sent to active the dedicated protection scheme. But if fault is still not restored, the shared protection scheme will be activated. The monitoring signal section is responsible for sensing fault and its location whereas generation of activation of signal is sent by activation section in controller system.

For switching the service from a failed working path to a backup path, then the backup path has to be set up (Schupke *et al*., 2003). 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 disjointed 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. Figure 2 represents the restoration scheme proposed in various probability of fiber failure at the user side. The two optical switches are allocated in the transmission line in which both ONU and splitter are located. 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 it to the local ONU (end user). So the invention of this protection scheme will provide for continuous signal flow since the mechanism architecture provide the protection line and neighbours protection line.

Normal condition: Figure 3 represents the green arrow that shows the normal network condition when there is no failure occurs in working line. In normal situation, the optical signals that represented as green arrow will directly pass through in the working line and enter the optical switches (which are 1x2 and 2x1).

First order failure: Figure 4 shows the failure when it is detected in working line, protection mechanism will be activated and optical switch will convert the optic signal

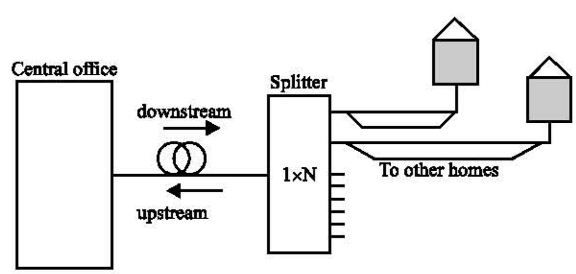

Fig. 1: Distribution fiber architecture starts from 1xN Optical Splitter until ONU. Two fibers are used which stand for working and protection line respectively

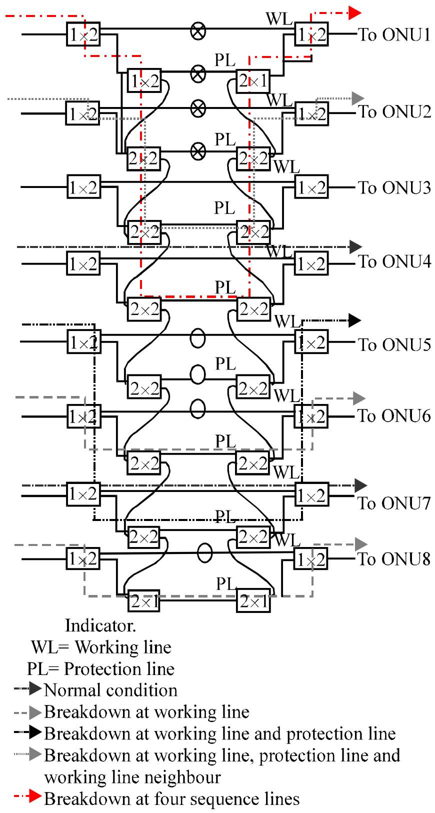

Fig. 2: Restoration scheme mechanisms for various failures. Each line is connected in Zig Zag manner to enable the traffic to be shared among the lines

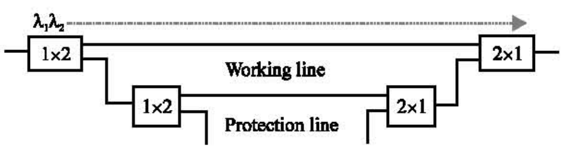

Fig. 3: Protection mechanisms in ideal condition

direction to the protection line. The purple arrow shows the protection mechanism as dedicated protection. So here, the optic signal will pass through into 4 optical switches (in working and protection line).

Second order failure: Figure 5 shows shared protection scheme when breakdown occurs in both line which is in working line and protection line. Shared protection scheme will be activated and optic signal will be converted to neighbor line protection as depicted in blue arrow. So under this second order failure situation, the optic signal will use neighbour line protection to restore the fiber fault.

Third order failure: Figure 6 shows the breakdown occurs in 3 sequences of lines and shared protection

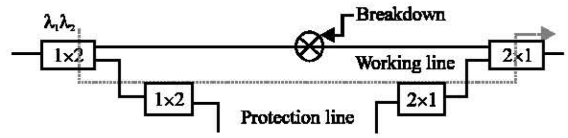

Fig. 4: Breakdown at working line and signal is diverted to the protection line

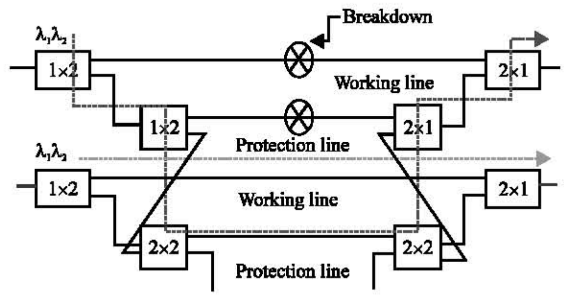

Fig. 5: Breakdown at working line and protection line. Signal diverted to the neighbour protection line

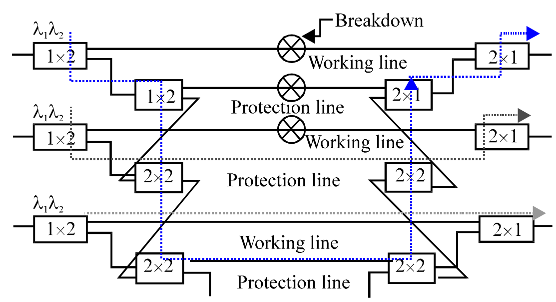

Fig. 6: Breakdown at working line, protection line, and working line neighbor.

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 green arrow. The yellow arrow represents the protection mechanism which converts the optic signal to the second neighbour protection line as the first neighbour protection used for dedicated protection (purple arrow).

IDEAL CONDITIONS ANALYSIS–SIMULATION APPROACH

The FTTH base network design was modeled and simulated using the Optisystem CAD program by Optiwave System, Inc. 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

Table 1: Simulation parameter based on the failure order conditions

Component	Normal condition	First order failure	Second order failure	Third order failure
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
1x8 Optical Splitter (dB)	3	3	3	3
Circulator Loss (dB)	2	2	2	2
Optical Fiber Loss (dB)	5	5	5	5
Optical Switch Loss (dB)	2.4	4.8	7.2	9.6
Total Loss (dB)	25.8	28.2	28.9	32.5

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/s 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 (1 dB), bidirectional optical splitter (3 dB), 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 (2.4 dB) 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/s 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 shown in Table 1. Total loss is a summation of all components loss used in simulation depending on failure orders. Present results were obtained by observing bit error rates, eye diagrams, optical power levels and dispersion levels.

NON-IDEAL CONDITIONS ANALYSIS–ANALYTICAL MODELING

Under non ideal conditions, the average received power needs to be increased in order to maintain the same system performance. This study also includes the power penalty study in order to investigate the effect of power penalty value against the optical switch cascaded in our network design since the simulation result may not define the impairment due to power penalty caused by optical switch. Power penalty can be defined as the minimum average optical power required by the receiver increases because of such non ideal conditions. This increase in the average received power is referred to the power penalty. Optical switches are mainly used in optical add/drop, optical cross and connection (OXC) system. Otherwise in our design, we used an optical switch to divert the working line in presence of fiber break.

In our analytical model for power penalty in optical switch, we extended the previous work from (Shen *et al*., 1999) in which the optical switch is analyzed in optical cross connect nodes (OXC). According to 2x2 OXC in fully loaded, OXC will be interfered by M+N-2 homodyne crosstalk contribution, N-1 which are leaked by the optical switch, and the other M-1 are leaked by the multiplexer or demultiplexer pair. In 2x2 Optical switch, the element of demultiplexer and multiplexer is not exist in the architecture, and we can assume the value of M is equal to 1 which mean the incoming wavelengths from one input port are not separated before going for switch. Since the optical switch will receive one number of wavelengths in the same time and the wavelength enters the optical switch may not be spatially separated by demultiplexer. Power penalty introduced in network is said is as the increase in signal power required (in dB) to maintain the same bit error rate in the presence of impairments (Alwayn, 2004). So one of the elements needs to be highlighted in this work is an optical switches included in our proposed restorations FTTH network. The maximum power penalty (pp) caused by N-1 crosstalk contribution leaked when passing through the optical switch because of non ideal crosstalk specification of optical switch is given by:

$$\text{Power penatly (dB)} = 10\log 10 \frac{Pi_{mp}}{P_{noimp}} \qquad (1)$$

Where:

P_{imp} = Power required with impairment

$P_{no\ imp}$ = Power required without impairment

$$Pp\ (dB) = -5 \log (1-4\ \alpha^2_{RIN} Q^2)$$

$$Pp\ (dB) = -5 \log [1-4x \in x(N-1)xQ^2] \qquad (2)$$

where, Q is the Q factor corresponding to the reference BER, α^2_{RIN} is the auto covariance of the beat noise resulting from interferometric intensity noise and N is the number of input output port for optical switch å. In our protection scheme design, 2x2 optical switch had been used.

RESULTS AND DISCUSSION

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. Figure 7a-d show the eye diagram for downstream wavelength. Clear opening eye diagram were observed for condition failure A rather than 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 extracted from eye diagram analysis such as Q factor, eye opening, jitter, and BER value for all condition types based on the simulation results. All these values are divided in various failure types which have different received power. Jitter is explained as how early or late a signal transition is with reference to when it should transition. The waveform has two different rising and falling edges, denoting the presence of deterministic jitter. From the observed eye diagram, there is a reduction in eye opening, BER and Q factor for failure condition when it use many protection route to implement the restoration scheme as in third order failure.

For every number of optical switches, 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 = $1x10^{-9}$) was achieved. For every type of protection mechanism, we employ the dedicated protection and shared protection. According to the four failure conditions which is normal condition, first order failure, second order failure, and third order failure

Table 2: Signal parameters in jitter, eye opening, BER and Q factor values obtained from the eye diagrams analysis for 1550 nm wavelength

Failure condition types	Analysis	Wavelength 1550 nm
Normal condition (received power. -25.8 dBm)	Jitter	0.0409935
	Eye Opening	5.21E-06
	BER	1.00E-258
	Q Factor	34.3021
First order failure (received power -28.2 dBm)	Jitter	0.0559126
	Eye Opening	2.82E-06
	BER	1.00E-97
	Q Factor	20.8805
Second order failure (received power -28.9 dBm)	Jitter	0.0561559
	Eye Opening	2.32E-68
	BER	1.00E-68
	Q Factor	28.9
Third order failure (received power -32.5 dBm)	Jitter	0.120794
	Eye Opening	7.50E-07
	BER	1.00E-15
	Q Factor	7.77955

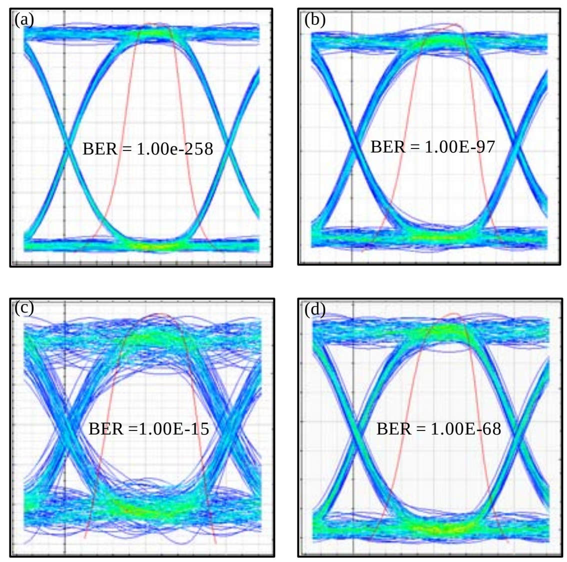

Fig. 7: Observed eye diagrams for (a) 1550 nm downstream at condition failure A (b) 1550nm downstream at condition failure B (c) 1550nm wavelength at condition failure C (d) 1550nm wavelength at condition failure D

the protection route will involve in two, four, six and eight numbers of optical switch respectively. Figure 8 shows the eye diagram for (a) the downstream data at 1.25 Gb/s in -34 dBm sensitivity and (b) -25 dBm sensitivity for normal condition case. From the result achieved, the simulation model was simulated in -25 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

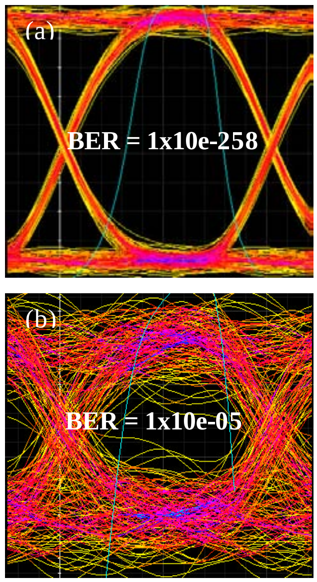

Fig. 8: Eye diagrams observed from 1550 nm wavelength in (a) -34 dm sensitivity (b) -25 dBm sensitivity

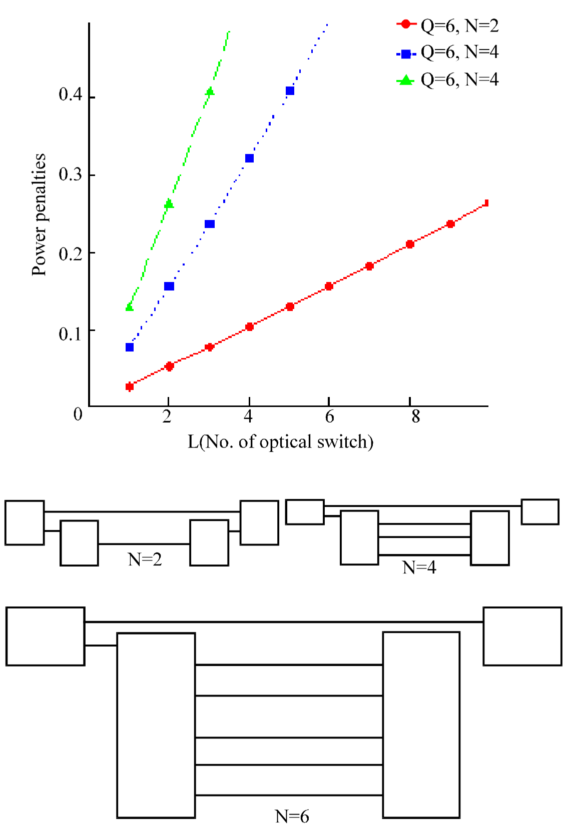

Fig. 9: Power penalties in various failure conditions which the number of ports increased

that receiver sensitivity managed to be adjusted in -25 dBm sensitivity using goal attainment type of optimization which is commonly used for parameter extraction. Then the thermal noise of a PIN is extracted to obtain receiver sensitivity equals to -25 dBm. For this simulation we set the receiver sensitivity to-34 dBm by using the single parameter optimization. From the result achieved, the proposed architecture design in all condition can only be 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).

In non-ideal condition analysis, the power penalty is said increasingly due to the optical switches number used in optical network. The highest value of power penalty achieved from the third order failure which is used 8 numbers of optical switches in a restoration path. Based on Eq. 1, Fig. 9 is achieved in order to see the power penalty obtained from different cases. Figure 9 shows that when the value of BER requirement is fixed, the power penalty caused by optical switch crosstalk increases with adding more input-output port numbers (N) in optical switches (N = 2, N = 4, N = 6). When we fixed the Q number and varied the N, then the power penalty (dB) increased quickly at high value.

CONCLUSIONS

In this study we provide the protection and restoration scheme against various failure conditions in order to maintain and provide the network survivability for FTTH network architecture. Then through the proposed scheme, analysis for ideal and non ideal has been done to illustrate the system performance in various failure orders in distribution fiber. Furthermore we represent the ideal analysis conditions in eye diagram analysis and for non ideal we the power penalties issues are discussed. The simulation model and the results were presented to convince proposed protection scheme. From the result achieved, the receiver will gives viable system performance up to fourth order of failure using our proposed protection scheme in an ideal condition analysis above. 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 in both upstream and downstream directions.

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