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A Novel Protection Architecture Scheme for EPON

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Abstract: With the rapid development of the Internet and extraordinary increase of bandwidth requirement, fiber based networks emerge and become more and more popular. The EPON (Ethernet Passive Optical Network) technology, which combines the mature Ethernet technology and high-bandwidth PON technology, is an ideal access method to achieve fiber based network service and appears to be the most widely-used access network. Thus, information reliability is becoming more and more important, making the protection of fiber based networks more and more necessary and crucial. Nowadays most EPONs are protected against failures by adopting redundant network equipments. This study proposes a novel protection method for EPON, which is more reliable and safer than existing schemes. This protection architecture scheme is able to provide protection for EPON and point out the exact failure reason for further physical recovery and repairing by the Network Management (NM) Server. Actual operations show that the proposed scheme can provide protection for at least three types of failures, i.e., the ONU link failure, the OLT link failure and the OLT failure.

Key words: High-reliability, FTTH, EPON, OLT, ONU, topology

INTRODUCTION

Recently, with the rapid development of the Internet and extraordinary increase of bandwidth requirement, more and more Internet business has gradually entered numerous households and then bottlenecks of bandwidth in access networks emerge (Luo *et al*., 2005; Jaehyoung *et al*., 2008; Xiong *et al*., 2007; Asiedu and Feng, 2003). FTTx (Fiber-To-The-x, x can be home (H), building (B) and curb (C)) networks have always been the ultimate solution to a future broadband access network to overcome these bottlenecks. In recent years, several technological developments have brightened the outlook on FTTH (Luo *et al*., 2005; Ab-Rahman *et al*., 2009). The PON (Passive Optical Network) technology is best suitable for FTTH deployment due to its low Operating Expenditure (OPEX) (Jaehyoung *et al*., 2008). There are several kinds of PONs, such as ATM-PON, EPON, GPON, WDM-PON, etc. (Han *et al*., 2006). Among them, the EPON technology, which combines a mature Ethernet technology and high-bandwidth PON technology, is an ideal access method to achieve integrated services (Xiong *et al*., 2007).

Nowadays, Information security is becoming more and more important in some special environment as the number of data being exchanged on the Internet increases every day (Liu *et al*., 2008; Zaidan *et al*., 2010). In designing EPON, reliability is of the same important as cost effectiveness (Vaughn *et al*., 2004). Thus, the protection scheme becomes more and more important and necessary to ensure the reliability and security of information transmission in EPON. A protection architecture scheme in access networks should be able to protect the access network against failures due to fiber cut(s) or failure of OLT(s) (P'ng *et al*., 2005). ITU has recommended four protection architecture schemes, two of which are able to provide protection for ONU link failures and three of which are able to provide protection for OLT link failures. Hossain *et al*. (2005) proposed a novel Ring-Based EPON Architecture to advance the research in ring EPON architecture in 2005. However, these schemes are often found not reliable enough in some special environment where information security and reliability are strictly required. Under above circumstances, this study proposes a high-reliability protection architecture scheme for EPON to avoid data and information loss. And it is able to provide protection for three types of failures, i.e., the ONU link failure, the OLT link failure and the OLT failure and the exact failure reason is also depicted in the Network Management Server for further physical system recovery.

EXISTING PROTECTION SCHEMES FOR EPON

In EPON, an OLT always has to accommodate multiple ONUs (For example, 16). For information security and reliability, the protection architecture is a very important and absolutely necessary issue. In the ITU-T Recommendation G.983.1, four types of protection network architectures have been proposed (Vaughn *et al*.,

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2004). In the first protection network architecture as shown in Fig. 1, the spare fiber could be utilized as a backup link when the fiber breaks. However, all ONUs would be useless when the OLT doesn't work. The second architecture in Fig. 2 specifies the full duplication of the EPON system. This architecture provides full protection for the network. But if both EPON links (for example, ONU#1-PON#1 and ONU#1-PON#2) connecting to one ONU are broken, then the ONU will be useless. What's more, when both PONs of OLT (for example, OLT#1-PON#1 and OLT#1-PON#2) fail, the whole system is useless either. The third ITU-T architecture in Fig. 3 is with redundant OLT PON systems. The primary OLT is normally working and the secondary is used as a cold standby. The backup equipments are not utilized even if there are no failures, thus it is not economical. And the disadvantages of the second architecture also exist in the third architecture. The fourth architecture in Fig. 4 offers independent duplication of branch and common lines. If both PONs of OLT (for example, OLT#1-PON#1 and OLT#1-PON#2) don't work, the whole system is useless. What is worse, it utilizes a lot of redundant equipments, thus it is not only uneconomical but also too complicated to be considered attractive.

While extensive research attention was focused on EPON tree architecture, ring architecture is being paid more and more attention nowadays. But more fiber usage is needed and higher signal attenuation emerges due to longer fiber path in the Conventional ring architecture. So, Hossain *et al.* (2005) proposed a novel Ring-Based EPON Architecture shown in Fig. 5 to overcome these

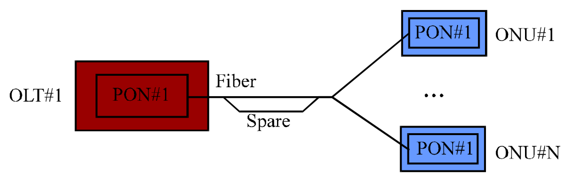

Fig. 1: EPON protection architecture 1 recommended by ITU-T

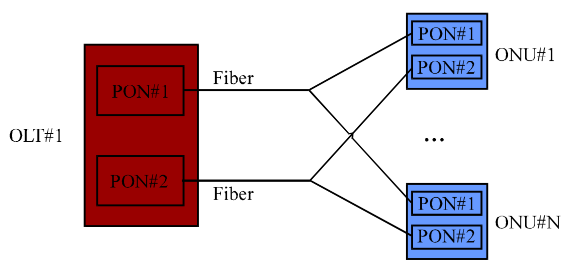

Fig. 2: EPON protection architecture 2 recommended by ITU-T

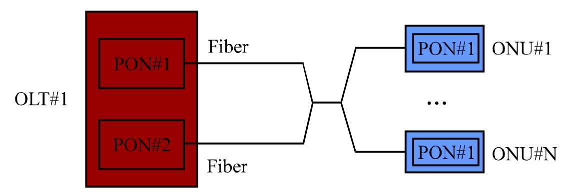

Fig. 3: EPON protection architecture 3 recommended by ITU-T

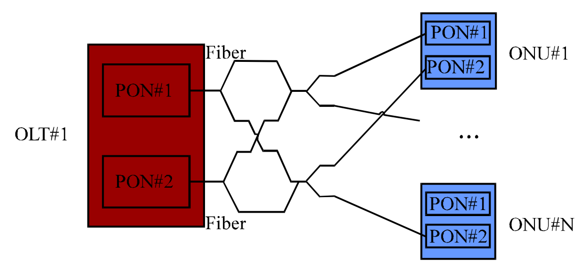

Fig. 4: EPON protection architecture 4 recommended by ITU-T

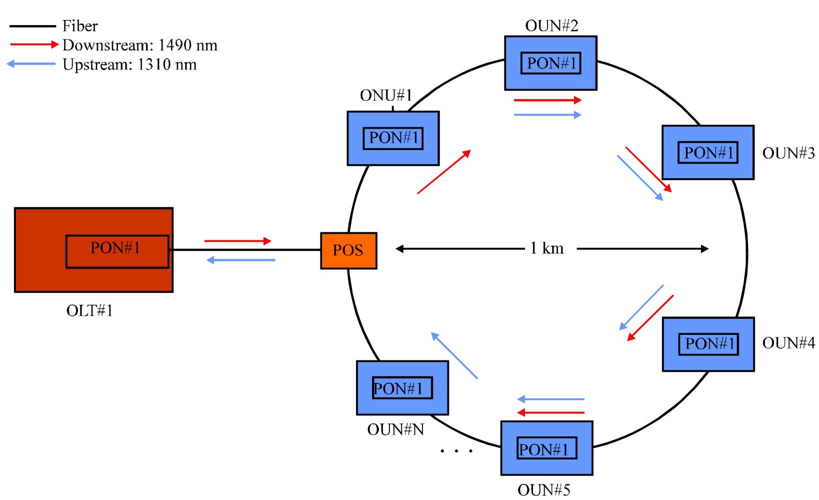

Fig. 5: A Novel Ring-Based EPON Architecture proposed by Hossain *et al.* (2005)

disadvantages. However, if the only PON in OLT(OLT#1-PON#1) doesn't work, then all ONUs will be out of work. Similarly, if the only PON in ONU(ONU#1-PON#1) is failed, ONU#1 can't work either. What's worse, the ONUs which are behind ONU#1 in the ring architecture(For example, in Fig. 5, ONU#2, ONU#3, ONU#4, ONU#5, … and ONU#N) can't work either because their downlinks are cut off which cause that they can't get message or data from OLT#1 any longer.

PROPOSED PROTECTION ARCHITECTURE SCHEME

The EPON system is composed of OLT (Optical Line Terminal), POS (Passive Optical Splitter) and ONU (Optical Network Unit). EPON can support a maximum distance of 20 kilometers and it uses 1310 and 1490 nm wavelengths, 1310 nm for upstream (from ONU to OLT), while 1490 nm for downstream (from OLT to ONU). Figure 6 depicts the EPON architecture.

The downstream transfer from OLT to ONU is carried out by Point-to-Multipoint (P2MP) broadcast method. This feature easily allows video multicast/broadcast services to be provided. Figure 7 describes the EPON downstream transfer process. On the other hand, the upstream transfer from ONU to OLT is carried out by point-to-point method and adopts the TDM (Time Division Multiplex) protocol. Figure 8 describes the EPON upstream transfer process.

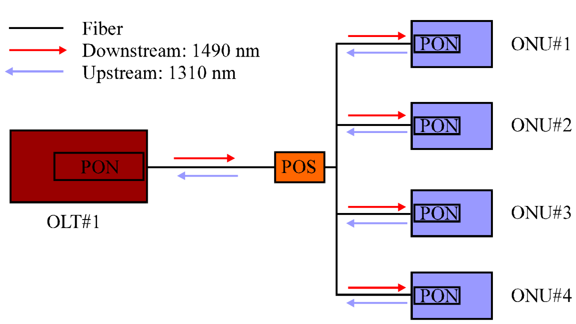

Fig. 6: Basic network architecture of EPON

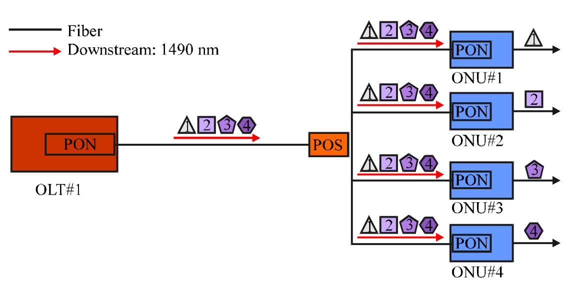

Fig. 7: Downstream in EPON

We propose a protection architecture scheme of high reliability as below. As shown in Fig. 9, in our scheme, both OLT and ONU have two PON modules, which are useful to the link protection of the whole EPON system. Furthermore, we adopt a new topology called hand-in-hand EPON protection architecture in Fig. 9 to develop the EPON architecture and increase the reliability of EPON system.

The proposed scheme is at least capable of providing protection against three types of failures, i.e., the ONU link failure, the OLT link failure and the OLT failure. As shown in Fig. 10, if there are some fiber failures between Point A and Point B (i.e., A-B failure), we call it the ONU link failure. In this case, ONU#1 will change to the other PON link(ONU#1-PON#2) as soon as the currently-used PON link(ONU#1-PON#1) is failed, such that data loss is avoided and the EPON system is protected. In the second case, the OLT link failure emerges when there are some fiber failures between Point B and Point C (i.e., B-C failure), causing the link failure to both ONU#1 and ONU#2 that have registered to OLT#1 through the PON link OLT#1-PON#1 before. In order to avoid information loss, both ONU#1 and ONU#2 will change their current PON link (OLT#1-PON#2) to the other one and register to OLT#2 as soon as possible. Similarly, for the third case, there is an example of the OLT failure showed in Fig. 10.

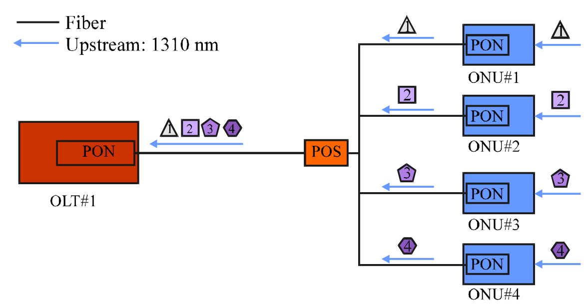

Fig. 8: Upstream in EPON

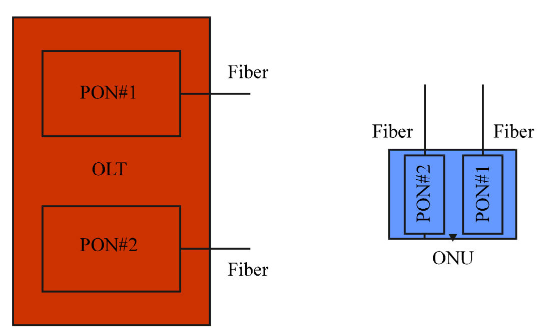

Fig. 9: OLT and ONU with two PONs in our proposed scheme

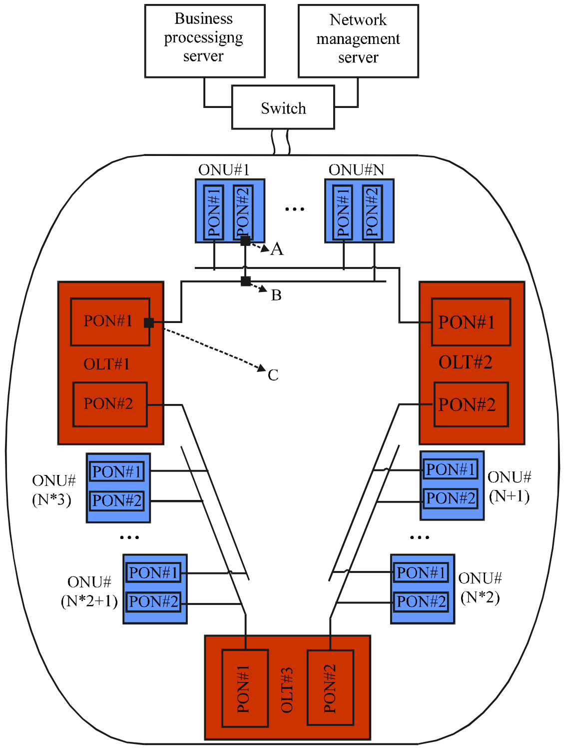

Fig. 10: The proposed protection architecture scheme

All the ONUs (For example, ONU#1, ONU#2 and ONU#(N*3)) registering to OLT#1 will change their current PON link to the other one and register to the other OLT (ONU#1 and ONU#2 register to OLT#2, while ONU#(N*3) registers to OLT#3) as soon as a failure emerges in OLT#1.

Once a signal loss is detected, the protection control unit will determine which type of failure (the ONU link failure, the OLT link failure or the OLT failure) it is and then find out the faulty OLT, the faulty PON link or the faulty ONU, depicting them on the Network Management Server for further physical recovery and repairing.

RELIABILITY ANALYSIS

As shown in Fig. 11, we adopt a testing system with three OLTs and only six ONUs to briefly explain the reliability of our proposed protection architecture scheme which is called hand-in-hand architecture. In this testing system, ONU#1 registers to OLT#1 through OLT#1-PON#1; ONU#2 registers to OLT#2 through OLT#2-PON#1; ONU#3 registers to OLT#2 through OLT#2-PON#2; ONU#4 registers to OLT#3 through OLT#3-PON#2; ONU#5 registers to OLT#3 through OLT#3-PON#1; while ONU#6 registers to OLT#1 through OLT#1-PON#2.

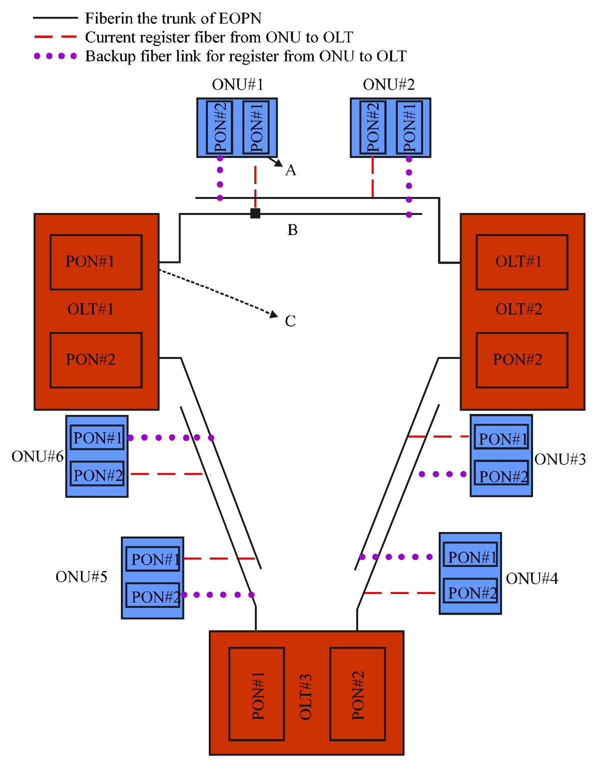

Fig. 11: An example testing system with three OLTs and only six ONUs

Table 1: Reliability comparison among the proposed scheme and ITU-T architectures

	Failure area			
Architecture	ONU link failure (A-B)	OLT link failure (B-C)	OLT#1	OLT#1 and OLT#2
ITU-T Architecture 1	ONU#1 useless	All ONUs useless	All ONUs useless	All ONUs useless
ITU-T Architecture 2	usable	usable	All ONUs useless	All ONUs useless
ITU-T Architecture 3	ONU#1 useless	usable	All ONUs useless	All ONUs useless
ITU-T Architecture 4	usable	usable	All ONUs useless	All ONUs useless
Hossain *et al.*'s Architecture	All ONUs useless	All ONUs useless	All ONUs useless	All ONUs useless
Proposed architecture	usable	usable	All ONUs usable	ONU#1 useless; ONU#2 useless. While: ONU#3 usable; ONU#4 usable;ONU#5 usable; ONU#6 usable

Now we compare our proposed scheme with the four architectures recommended by ITU-T and Hossain *et al.*'s Architecture. As shown in Table 1, when some fiber failures between Point A and Point B occur (the ONU link failure), we find that ONU#1 is no longer usable in the ITU-T architecture 1 or ITU-T architecture 3, because there is no fiber link to OLT and it is worse in Hossain *et al.*'s Architecture, first, ONU#1 is no longer usable because there is no fiber link to OLT, secondly, the ONUs which are behind ONU#1 in the ring architecture(For example, ONU#2, ONU#3, ONU#4, ONU#5 and ONU#6) can't work either because their downlinks are cut off. while ONU#1 in the ITU-T architecture 2, ITU-T architecture 4 and our proposed scheme is still usable. When some fiber failures between Point *B* and Point *C* emerge (the OLT link failure), all the ONUs in the ITU-T architecture 1 or Hossain *et al.*'s Architecture are no longer usable because there is no spare fiber in this system for fiber link backup, while all ONUs in the ITU-T architecture 2, ITU-T architecture 3, ITU-T architecture 4 and our proposed scheme is still usable because of the OLT spare fiber for backup. What's worse is that all ONUs in the ITU-T architecture 1, ITU-T architecture 2, ITU-T architecture 3, ITU-T architecture 4 or Hossain *et al.*'s Architecture are useless when all PONs in the OLT#1 are failed, while our proposed scheme is still usable because of backup OLTs. In this testing system, if both PON#1 and PON#2 of OLT#1 are failed, then ONU#1 will change its current PON link and register to OLT#2 through the fiber link OLT#2-PON#1, while ONU#6 will change its current PON link and register to OLT#3 through the fiber link OLT#3-PON#2 as soon as possible to avoid information loss.

Furthermore, what will happen if all PONs in two OLT don't work? Taking OLT#1 and OLT#2 for example, we can obviously find that all ONUs in all of ITU-T architectures are no longer usable. But in our proposed scheme, ONU#3, ONU#4, ONU#5 and ONU#6 are still usable because they could register to OLT#3. Of course, ONU#1 and ONU#2 are useless yet for there is no fiber link to available OLT now. From the charts, it is clear that the proposed protection scheme is more effective, reliable and safer than existing schemes because it can provide protection for at least three types of failures. When the ONU link failure occurs, this ONU will change its link to the other link through the spare PON standing by. And the ONUs related will register to the OLT through the other spare PON link standing by as soon as the OLT link failure emerges. While the OLT failure occurs, all ONUs will register to another OLT as soon as possible to avoid data loss.

CONCLUSIONS

This study proposed a novel protection architecture scheme of high reliability for EPON. It is found that this protection scheme is able to provide protection for EPON and also could point out the exact failure reason for further physical recovery and repairing by the Network Management Server. The proposed scheme can provide protection against at least three types of failure, i.e., the ONU link failure, the OLT link failure and the OLT failure.

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