NOVEL ACTIVE MONITORING OF CUSTOMER PREMISES USING BLUETOOTH IN OPTICAL ACCESS NETWORK

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Abstract: A new rerouting scheme and spare capacity planning for optical link failures is demonstrated employing Bluetooth monitoring. Optical networks require adequate fault monitoring in order to accurately identify and locate network failures. Detailed physical layer information as well as link surveillance is carried to OLT for in-situ monitoring of QoS.

1. INTRODUCTION

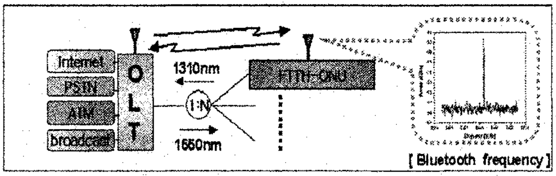
Progress in optical networking has stimulated development in optical performance monitoring (OPM), particularly regarding signal quality measures such as optical signal-to-noise ratio(SNR), Q-factor and dispersion[1-2]. The need for fault management capability in the transmission media is also driven by expansion of optical access networks. One possible fiber network architecture for FTTH(Fiber To The Home), PON(Passive Optical network) system consists of a number of cascaded passive optical power splitters or AWGs(Arrayed Waveguide Gratings), originating from a single optical fiber and it may be terminated at the customer premises with optical nodes. The maintenance of such passively split networks presents a new set of challenges to service providers, as due to the star topology, the various branches of the network are likely be equidistant from the transmitter such that they cannot be sensibly probed and addressed from the head-end via a conventional maintenance instrument such as the optical time domain reflectometer(OTDR)[3]. Additionally, present monitoring techniques have been mainly concerned on optical path itself and detailed functional information of the physical layer in the customer's premises, such as optical network unit (ONU), has not been thoroughly attempted due to complexity in optically multiplexing the monitored information over the main signals.

Bluetooth is an open wireless specification that enables short-range connections between communication devices[4] at a frequency of 2.4 GHz within the maximum link distance of 1.2km. We propose a novel monitoring technology in optical access networks by transporting the monitoring signal of ONU functional information over the bluetooth, based on which optical path is can be self-healed, for the first time.

2. EXPERIMENTS

A schematic of the proposed system is shown in *Figure 1*. We assumed bi-directional PON (Passive Optical Network) system for fiber to the home (FTTTH) environment where downward signal is carried over 1550nm and upward signal over 1310nm. Fast ethernet media converters(MC) operating at 100Mbps were designed and fabricated for fiber to UTP conversion at the ONU in the customers. Information on key operating parameters for physical medum dependents(PMD) in ONU are monitored in real time and sent over Bluetooth using a synchronized antenna pair, one at ONU and the other at Optical Line terminal (OLT). Bluetooth supports only 780kb/s, which may be used for 721kb/s unidirectional data transfer(57.6kb/s return direction) or up to 432.6kb/s symmetric data transfer. The proposed system also include self-healing network function, by employing optical MEMS switch for optical routing in the case of fault and error in either optical path or PMD in ONU. Note that the communication over Bluetooth will not interfere with optical signals in the wired network and the its communication range of 1 km do cover most of deployed FTTH systems.

In ONU, the downstream signal is monitored in both optical and electronic domain. Optically 1510nm power is monitored using a broadband tap coupler, which reflects the real time optical link power budget. In the electronics, the fault-error detection output from the MC is monitored for QoS. Furthermore inside temperature and humidity of ONU are monitored to cope with an abrupt surge. These downstream monitoring information is time division multiplexed for every 8 bit using RS232C and sent to the corresponding antenna at OLT over Bluetooth. At OLT, the optical power of the upstream signal at 1310nm is monitored, which serves a redundant check for the real time optical link power budget. Similar to ONU, temperature and humidity of OLT are monitored. These uptstream monitoring signals at OLT are multiplexed in RS232C and sent to the antena in ONU.



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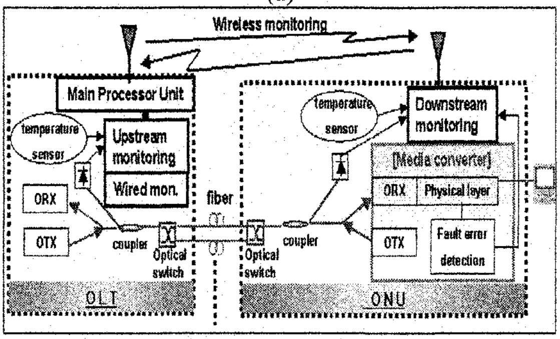


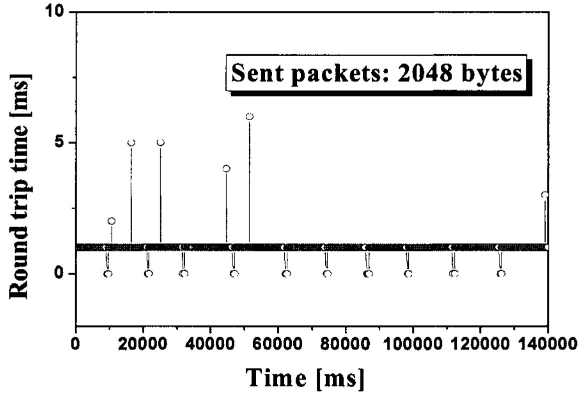
(b

Figure. 1. (a) Experimental set-up for bluetooth monitoring
(b) Physical layer status and optical power monitoring

2.1 Self healing mechanism using bluetooth

An example Note that in the proposed scheme, transmittion failure due to optical link damage can be detected in redundant manner, firstly by optical power monitoring of 1550nm at ONU, and its Bluetooth signal and sencondly by optical power monitoring of 1310nm upstream at OLT. In the case of failure of these monitoring signals, the optical path can be self-healed by switching to the spare optical route using a 2x2 MEMS switch. Local switching capability at ONU and OLT would be highly beneficial for faster response of system restoration[5-6].

In order to test the self-healing capability, we have simulated fiber cut by plugging in and out the fiber connectors and the temporal responses of the system to switch to other optical path have been measured. Ping protocol that travels to a distant IP address back and forth over the link, was used to measure the round trip time for the packets of 2048 bytes in the link. For 10 simulated occasions of fiber cut, distribution of the roundtrip time is shown *in Figure. 2*(a). Average round trip time was around 1ms and restoration time for the network was in average 380 ms, which included MEMS response time of 0.5 msec as well as bluetooth transmission and protection-information processing time.



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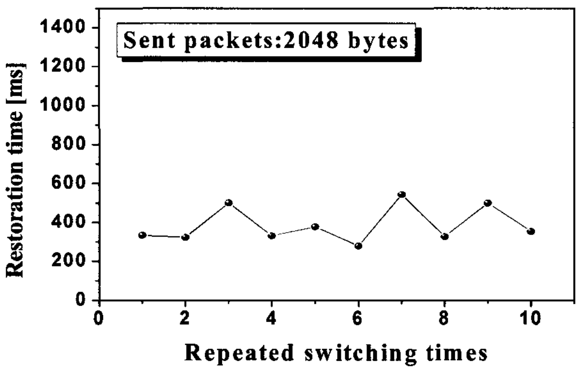


(b)

Figure.2 (a) Round trip time for fiber cut occasions
(b) System restoration time for fiber cut

The distribution of restoration time is shown *in Figure. 2*(b). The minimum was 270msec and the maximum was 550msec. The latency of the system was found to be reliable in spite of wireless transmission.

Figure.3 represents distribution of the number of lost packets during the system restoration as described earlier. Individually, 32bytes packets were sent. Maximum of 10 packets were lost and the average packet loss was approximately 18% in the case of 32 bytes packet transmission. It is observed that the loss rate significantly reduces as the transmitted packet size increases, so that about 0.3% loss rate for 2048 byte packets.

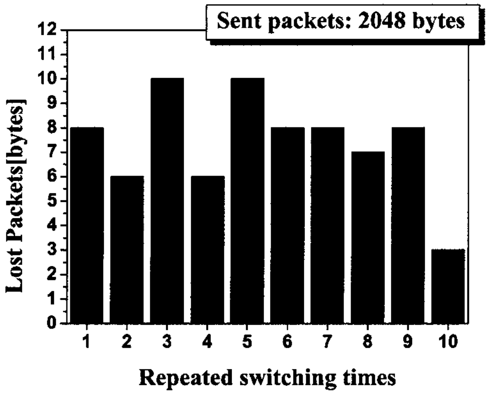
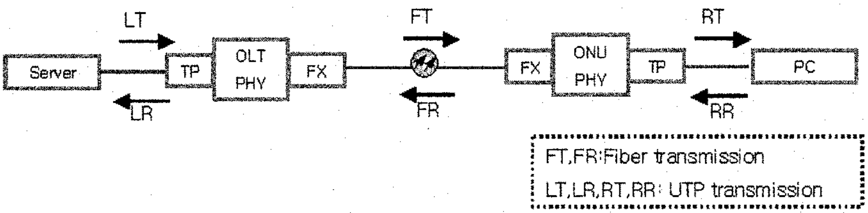


Figure.3 The number of lost packets for damage

2.2 Physical layer monitoring technique



Condition (auto-negotiation	OLT Physical layer				ONU Physical layer			
	TP		FX		FX		TP	
	Link	Fault	Link	Fault	Link	Fault	Link	Fault
LT fault	off	on	on	off	on	on	off	off
LR fault	off	off	on	off	on	off	on	off
LT & LR fault	off	on	on	off	on	on	off	off
FT fault	off	off	on	on	off	on	off	off
FR fault	off	off	off	on	on	on	off	off
FT & FR fault	off	off	off	on	off	on	off	off
RT fault	on	off	on	off	on	off	off	off
RR fault	off	off	on	on	on	off	off	on
RT & RR fault	off	off	on	on	on	off	off	on

Figure.4 Fault location algorithm

Fiber-optic signal detects signal which indicates whether or not the fiber-optic receive pair is receiving valid signal levels. So far, although the network fault manager receive alarms for some network failures, it's not easy to know which line or part causes faults between OLT and customer premises. As shown in *Figure.4* , this algorithm can minimize the time to find and to correct fault location. For example, TP(link-on),TP(fault-off),FX(link-on)and FX(fault-off) on OLT physical layer and FX(link-on),FX(fault-off),TP(link-off) and TP(fault-off) on ONU physical layer let fault manager know UTP line(especially RT fault) connected to the customer device(PC) has a problem. Also, through wireless monitoring, fault location could be recognized and resolved in spite of the fiber or the other lines cut.

3. CONCLUSIONS

In summary, the novel self-healing system was demonstrated by providing a composite Bluetooth monitoring and optical monitoring. The system can be readily applied to OLT-ONU links in FTTH environment. Symmetric upstream and downstream signals at 100Mbps were monitored and along with monitoring signals for temperature, humidity and fault error detection they are multiplexed over Bluetooth within 1km. The restoration time for optical path cut was less than about 500ms and less than 0.7% of packet was lost for 2048 byte packets.

Especially, system manager can easily monitor physical layer of each customer device through wireless communication in OLT. Also, fault location algorithm solution will reduce alarm processing time as well as ambiguity in fault localization. Furthermore, using mobile service with bluetooth such as PDA and mobile phones, we will have an opportunity to monitor various optical performance under ubiquitus environments.

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