Time estimation of logical optical line terminal migration for Elastic Lambda Aggregation Network

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Abstract: Elastic Lambda Aggregation Network (EλAN), the next-generation access and aggregation integrated network, has been proposed. In EλAN, Optical Line Terminals (OLTs) are programmable, and Logical-OLTs (L-OLTs) can be migrated between different P-OLTs. L-OLT migration leads to enhance failure resistance and improve power saving. We have experimentally L-OLT migration between P-OLTs in our laboratory. However it is necessary to evaluate how L-OLT migration time changes according to physical distance. Therefore we made an experiment of L-OLT migration in wide area network on JGN-X. This paper proposes estimation equation of L-OLT migration time. The equation leads to determine L-OLT arrangements considering time of L-OLT migration for physical distance.

Keywords: optical access network, optical aggregation, SDN, OpenFlow, EλAN, JGN-X

Classification: Network System

References


1 Introduction

By the spread of Fiber To The Home (FTTH) which is high-speed Internet access and the advent of video applications that require large bandwidth, Internet traffic has been rapidly increased. In addition, the traffic of the mobile network is also increasing rapidly due to the rapid spread of smartphones and high-speed wireless communication system. Moreover an expansion of network transmission capacity leads an increase in power consumption of network components.

In access network and metro network, each service including Internet, leased line, and mobile backhaul, has its own network. Therefore capital investment cost and operating cost increase. This is because each service network has its own requirement conditions such as protocol and Quality of Service (QoS).

From this background, a next-generation access and aggregation integrated network, named Elastic Lambda Aggregation Network (EλAN), has been proposed[1,2,3]. In EλAN, a programmable optical line terminal (P-OLT) provides logical OLTs (L-OLTs) and a programmable optical network unit (P-ONU) provides logical ONUs (L-ONUs). Each L-OLT is dynamically reconfigurable and support of variety of services. In order to maximize the programmability and reconfigurability, L-OLT migration among P-OLTs[4,5,6] for network energy consumption reduction and virtual OLT based disaster recovery method[7,8] has been proposed. However, L-OLT migration causes service intermittent time. Therefore, we are able to determine the distance
between L-OLTs for acceptable intermittent time by understanding the interruption time for L-OLT migration time in this paper. How long time is required for the migration is an important issue to apply the L-OLT migration to the actual service environment. Therefore, we make an experiment of L-OLT migration on the wide area network conditions and propose the estimation equation of L-OLT migration time in this paper.

2 Architecture of $E\lambda AN$

Fig. 1 shows the architecture of the $E\lambda AN$[1,3]. In $E\lambda AN$, L-OLTs, L-ONUs, and an active optical distribution network (ODN) using optical switches have flexibility to realize a variety of services and network configurations. By providing flexible access paths in response to service requests using the active ODN, $E\lambda AN$ increases the accommodation efficiency of the entire network.

$E\lambda AN$ integrates the current access network and metro/aggregation network into a single network. The active ODN connects L-OLTs and L-ONUs. Transmission distance between the L-OLT and the L-ONU is designed more than 40 km and a single L-OLT accommodates more than 256 L-ONUs. P-OLTs are located in central offices (COs) and connected to core network via virtual layer2 switch (VL2SW), which is constructed with distributed real L2SWs. VL2SW transmits traffic between the core network and P-OLTs and traffic between P-OLTs. The VL2SW, P-OLTs, and the active ODN are controlled through control plane by an $E\lambda AN$ network management system (NMS). The L-OLT migration is initiated by NMS. Fig. 1 shows the L-OLT migration example. When traffic between the L-OLT and L-ONUs is small, L-OLTs can be aggregated into small number of P-OLTs. Therefore, it is possible to sleep the unused P-OLTs in CO and reduce power consumption of CO. In Fig. 1, NMS gives trigger message to L-OLT#22 operating in the P-OLT#2 to migrate to P-OLT#1 in order to reduce power consumption of CO.

At the same time, NMS sends messages to the VL2SW and the active ODN to set switches to configure the access path between L-OLTs and L-ONUs. In the actual environment, NMS, P-OLT, VL2SW, and the active ODN switches are
physically separated in few m to few 10s km distance range. We make the estimation equation of L-OLT migration time from L-OLT migration experiments under long distance transmission conditions.

3 L-OLT migration experiment

We performed L-OLT migration experiment between P-OLTs with different physical distances to measure the required time. Fig. 2(a) shows the ELAN experimental network which is a part of the Interop Showcase network in iPOP2015[9].

![Structure of experimental network](image)

**Fig. 2. Details of L-OLT migration experiment**

P-OLT consisted of L-OLTs and software L2SW which was a part of VL2SW and implemented using Open vSwitch (OVS). In this experiment, L-OLTs and L2SW were made as software in Virtual Machine (VM).

In Fig. 2(a), Domain#1 was located in Koganei, and Domain#2 was located in Koganei, Yokohama and also Naha in order. The distance between Domain#1 and Domain#2 was defined as X. L-OLT migration was performed between P-OLT#1 (Domain#1) and P-OLT#2 (Domain#2) by changing the distance X. X between P-OLT#1 and P-OLT#2 set up in three patterns. In the first pattern, both P-OLT#1 and #2 were located in Koganei. The distance between P-OLT#1 and P-OLT#2 was 0 km (less than 20 m). In the second pattern, P-OLT#1 was located in Koganei and P-OLT#2 was located in Yokohama. The distance between P-OLT#1 and P-OLT#2 was 22.9 km. In the third pattern, P-OLT#1 was located in Koganei and P-OLT#2 was located in Naha. The distance between P-OLT#1 and P-OLT#2 was 1543.3 km. Fig. 2(b) shows geographic locations of Koganei, Yokohama, and Naha. Domain#1 was composed of P-OLT#1, L2SW, L2SW...
adapter for controlling L2SW via NMS using the OpenFlow protocol, traffic generator, and video server. Domain#2 was composed of P-OLT#2, an layer-1 switch (L1SW) which emulates the active ODN, an L1SW adapter for controlling an L1SW via NMS using the OpenFlow protocol, P-ONUs, and NMS.  Fig. 2(c) shows domain#2 in the Naha site. Two domains are connected by Ethernet virtual local area networks (VLANs) provided on JGN-X[10]. But in the first pattern (Koganei – Koganei), two domains were not connected on JGN-X. It is necessary to evaluate how L-OLT migration time changes according to physical distance. Therefore we set the distance between L-OLTs 1500km (Koganei – Naha). In EλAN, the actual target of L-OLT migration distance is up to 40km.

4 Experimentation results

As a first measurement, round trip times (RTTs) from NMS in domain#2 to OVSs in each P-OLT and adapters are measured using the ping command. The RTTs from the NMS to each device (OVS#1, OVS#2, L2SW adapter, L1SW adapter) were 0.313 ms, 0.421 ms, 0.248 ms, 0.190 ms in the first pattern, and 5.545 ms, 0.421 ms, 5.517 ms, 0.190 ms in the second pattern, and 42.111 ms, 0.225 ms, 41.944 ms, 0.256 ms in the third pattern. These times are RTTs average of 10 pings. This result shows that the time to send a message from the NMS to each device is increased in relation to physical distance.

Next, L-OLT migration time was measured. The start of the measurement was defined as the time that NMS sent message of L-OLT migration direction to P-OLT. The end of the measurement is defined when a new path is configured and end-to-end data transmission is resumed.

L-OLT migration time is determined as an average of the three measured L-OLT migration times. As a result, the L-OLT migration time between Koganei – Yokohama is 77.035 s, and between Koganei – Naha is 79.118 s. The process that spent much of the L-OLT migration time is VLAN configuration at the L2SW. This configuration time is device-dependent and nearly 70 s is required for VLAN setting and ports setting in this experiment. This time can be reduced to 30 s[5] and 4.5 s[11].

L-OLT migration time is divided into two parts. One is a distance-dependent part such as message transmission from NMS to each device. Another is a distance-independent part such as device configuration time. Therefore, L-OLT migration time is estimated using Eq. (1).

\[ t = \alpha \times X + t_{init} \]  

(1)

In Eq. (1), \( t \) [s] is L-OLT migration time, \( \alpha \) [s/km] is the proportionality constant, \( X \) is a distance of L-OLT migration, and \( t_{init} \) is a distance-independent device configuration time. Experimental results are plotted in Fig. 3 As a result, \( \alpha \) is estimated at 0.0014 [s/km] using Eq. (2).

\[ \frac{79.11768[s] - 77.0347402[s]}{1543.3[km] - 22.9[km]} = 0.0014[s/km] \]  

(2)
This value is varied according to the information amount of L-OLT and transmission rate at control plane. However, from the experimental results, since the information amount of L-OLT was relatively small, $\alpha$ can be treated as constant value. If the information amount of L-OLT is huge, $\alpha$ is bigger than 0.0014 [s/km]. $t_{\text{init}}$ can be divided into VLAN configuration time and other configuration times. The migration time between the same P-OLT (Koganei - Koganei) is 7.099 s. The VLAN configuration of L2SW is not changed in this migration. Therefore, $t_{\text{init}}$ can be described in Eq. (3).

$$t_{\text{init}} = t_{\text{VLAN}} + 7.099$$  \hspace{1cm} (3)

In Eq. (3), $t_{\text{VLAN}}$ [s] is device-dependent VLAN configuration time. Eq. (1)-(3) achieve to determine L-OLT arrangements considering of physical distance between L-OLTs.

### 5 Conclusion

We evaluated L-OLT migration time for physical distance between L-OLTs, and made L-OLT time estimation equation. As a result, estimation equation of L-OLT migration time for any physical distance was provided.

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