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A Generic Peer-to-peer File Sharing Architecture for Software-defined TWDMA-PON

I-Shyan Hwang, Ardian Rianto, Elaiyasuriyan Ganesan, Andrew Fernando Pakpahan, and Andrew Tanny Liem

Abstract-**In this paper, we propose a P2P file sharing architecture in TWDMA-PON with software-defined network (SDN) system to reduce inter- and intra-traffic to improve the quality of service (QoS). In addition, the proposed scheme employs colorless ONUs (tunable transceivers) to simplify the network operation, reduce installation cost, and enable easier maintenance. Moreover, we implement an integrated SDN with OpenFlow protocol to separate the control and data planes, enabling flexible and centralized control of the P2P intra-traffic. Simulation results demonstrate that our proposed scheme can realize QoS improvements up to 21% in the in terms of the packet delay, 23.9% in jitter, 13% in throughput, and reduce traffic-dropping up to 58% in scenario 6 (5:40:44:11) for the 1.5 ms cycle time.**

Keywords—P2P file sharing, TWDMA-PON, SDN, OpenFLow, QoS.

I. INTRODUCTION

Peer-to-peer (P2P) file sharing is a distribution application for sharing large files between nearby users [1], and its objective is to save bandwidth and support less delay [2]. According to [3] in 2016, the total consumer internet traffic for fixed networks was 52,678 petabytes (PB) per month, with P2P file sharing occupying 6,628 PB (12.5%) of the total fixed network traffic; and it is forecasted that from 2017–2021, the P2P file sharing will continue to occupy more than 6,500 PB traffic each month. As a result, ISPs are facing challenges in transporting the increasing volume of P2P traffic, with short timing and quality-of-service (QoS) requirements, by expanding the existing access network Infrastructure [4].

The standard passive optical network (PON) architecture consists of a centralized optical line terminal (OLT), multiples of optical network units (ONUs), and an optical splitter [5,6]. In addition, optical networks based on point-to-multipoint fiber and PONs use an optical splitter for facilitating a single fiber to serve multiple premises. There are two standardized PON systems, Ethernet PON (EPON) [7] and Gigabit PON (GPON) [8], that were standardized by the IEEE in 2004 and ITU-T in 2003, respectively. With the increase in multimedia traffic, the ITU-T defined the second next generation PON (NG-PON2) with 40-Gbit/s capacity PON system, which adopts time and wavelength division multiple access (TWDMA) technology [9]. TWDMA-PON multiplies the available transmission channels utilizing multiple wavelengths, i.e., wavelength division multiple access (WDMA) is used for different wavelength deployments, and time division multiple access (TDMA) is used for sharing the upstream transmission time, when multiple ONUs are configured in the same wavelength. The colorless ONU (tunable transceiver) is adopted by the NG-PON2 for reducing the computational effort of ONU digital hardware, supporting the wavelength channels in simplifying the network operation, reducing installation cost and maintenance effort [10].

Of late, software-defined networking (SDN) [11] promises increase the agility, enhanced security, automation, and lower capital (CAPEX) and operating expenditure (OPEX). The SDN focuses on the separation of control and data plane functions of the network, where the control plane decides the packet flow through the network, maintains, controls, and programs the data plane. Moreover, the SDN aims to follow the centralized programmable network model in which the OpenFlow protocol is used for adapting the SDN mechanism into network. In this paper, by taking advantage of the SDN with OpenFlow protocol in the TWDMA-PON, ISPs are rendered more flexible with centralized control over the P2P intratraffic file sharing application.

The rest of the paper is organized as follows: Section II discusses our proposed scheme and its operation. Section III describes the simulation and evaluates the system performance. Section IV presents the conclusion and future work.

II. PROPOSED ARCHITECTURE AND OPERATION

Figure 1 shows the SDN peer-to peer file sharing architecture on TWDMA-PON, and the system architecture and operation are described as follows.

A. *System Architecture*

1) *P2P-OLT*: includes the network-to-network interface (NNI), several line OLTs (L-OLTs), SD-agent, flow tables, and MAC control client which involves the discovery and registration process, REPORT processing, dynamic wavelength bandwidth allocation (DWBA), and GATE generation. The NNI is a physical interface that connects two or more networks using signaling internet protocol (IP). The L-OLT is a basic logical entity in OLT device structure, defined in IEEE Std. 802, and is responsible for the physical layer connectivity in EPON. In the discovery and registration process defined in multipoint control protocol (MPCP) for the OLT as well as ONUs, the OLT detects the newly connected ONUs, learns the round-trip delay,

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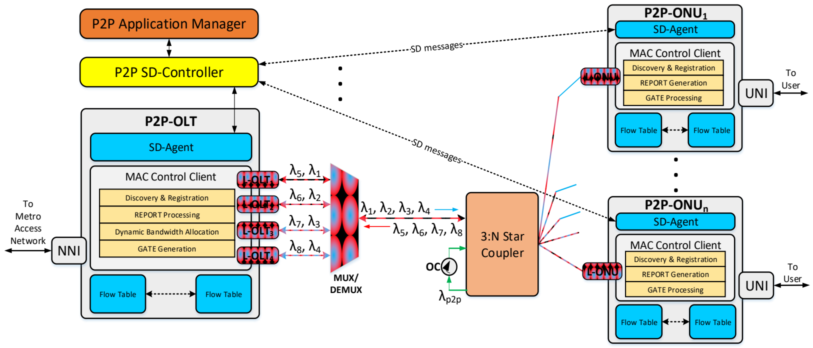

Fig. 1. The proposed Software-defined P2P File Sharing for TWDMA-PON system architecture.

and the MAC address of each ONU. REPORT processing, sent from ONUs to the OLT, obtains information on the traffic-queue length for each ONU, before executing the DWBA. The DWBA in OLT is for dynamically calculating and assigning bandwidth to each user, based on the information in REPORT message sent by each ONU. GATE generation is a process that generates a grant message, which including the grant start time, grant length, grant wavelength, etc., and the broadcast to each ONU.

2) *Colorless P2P-ONU,* shown in Fig. 2: includes the user-to-network interface (UNI), line ONU (L-ONU), SD-agent, flow tables, and MAC control client. The UNI is a physical interface for connecting users to the network. The L-ONU is a basic logical entity in ONU device structure, and is responsible for the physical layer connectivity in EPON. Each L-ONU contains a tunable transmitter, tunable receiver, and P2P-receiver. REPORT generation is a process that generates a report message with information on each ONU, and sends it to the OLT at a specific time allotted by OLT. GATE processing obtains information, such as grant start time, grant length, and grant wavelength of the traffic for each ONU, to start upstream transmission. There are four queues are used for EF, AF, P2P, and BE traffics, respectively. Tunable transmitters are tuned in the λ_5–λ_8 wavelength for upstream transmission and in the λ_{p2p} wavelength for P2P transmission, and tunable receivers are tuned in the λ_1–λ_4 wavelength for receiving downstream transmission.

3) *3:N Star Coupler:* includes an optical coupler and an optical circulator (OC). The optical coupler is a device that splits the optical signal from a fiber to several fibers, and reciprocally, combines the optical signals from multiple fibers into one. The OC redirects the optical signal from/to the optical coupler.

4) *P2P SD-Controller*: an SDN application that manages flow control to enable intelligent networking. The SD-controller, based on OpenFlow protocols, enables the servers to inform the switches, the location to which the packets are to be sent.

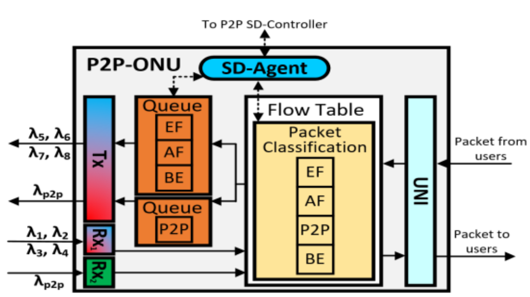

Fig. 2. P2P-ONU structure

5) *P2P Application Manager: (PAM)*: a software-based application for managing P2P file sharing application protocols.

B. Dynamic Wavelength Bandwidth Allocation (P2P-DWBA)

A new DWBA algorithm is proposed for our scheme, called *P2P-DWBA*, which is designed to handle traffic allocation. Our P2P-DWBA scheme supports intratraffic with four priority queues at each ONU, namely the EF, AF, P2P, and BE queues. When the OLT receives the REPORT messages, it initially defines the packet and calculates the timeslots required, according to each traffic type (EF, AF, P2P, and BE). The P2P-DWBA first checks the available and required timeslots for allotting all the requested timeslots for EF traffic. The P2P-DWBA then checks the remaining timeslots and allots the timeslot to AF traffic. After the EF and AF traffic timeslots have been allotted, the P2P-DWBA checks the remaining timeslots and if they are still available, it allots a timeslot for intratraffic (P2P); finally, the remaining timeslot will be allotted to BE traffic. After the P2P-DWBA calculates the timeslots for all the traffic, the OLT sends a GATE message {start_time, length, wavelength} for each traffic to all ONUs.

C. Signaling Operation

In signaling control operation, the connection between the ONUs and OLT is based on the multipoint control protocol (MPCP). The auto-discovery mode is used for detecting newly connected ONUs, and for learning the round-trip delay and the MAC address of the ONU. The OLT sends a *discovery GATE* to ONUs to create a transmission opportunity for undiscovered ONUs, which respond to the OLT by sending a *REGISTER_REQ*. The OLT then replies to the messages from the ONUs by sending a *REGISTER* to them. Finally, the ONUs send a *REGISTER_ACK* to complete the discovery mode. The OpenFlow connection is established between the SD-controller and SD-agents by sending *OFPT_HELLO* messages each side. If the connection fails, an *OFPT_ERROR* message is sent. Flow tables are used to classify and separate traffic into EF, AF, P2P, and BE, and are managed by the SD-controller through the SD-agent in ONUs. The SD-controller cooperates with the PAM to determine, whether the request packet is P2P traffic. If it is P2P traffic, the SD-controller sends an *OFPT_FLOW_MOD* message to modify and update the flow table in the source and destination ONU. Henceforth, the source ONU places the packet into the P2P queue and waits for sending a *REPORT* message to the OLT. After the OLT receives the *REPORT* message, the P2P-DWBA starts to calculate the timeslots for all the ONU traffic in a cycle. Then, the OLT sends a *GATE* message with the starting time, time length, and wavelength to all ONUs. We use the λ_5–λ_8 wavelengths for upstream transmission and the λ_{p2p} wavelength for P2P transmission.

D. System Operation

The user network interface (UNI) in the colorless ONU receives a request from the user. The flow table separates the packet, based on the source/destination address, ToS, and TCP/UDP into the EF/AF/BE/P2P queues controlled by the P2P SD-controller. The ONUs generate *REPORT* messages for transmitting their local condition to OLT, in the previously assigned timeslots. The received *REPORT* message at the OLT is parsed and demultiplexed to the OLT REPORT processing, and is then passed to the DWBA for the bandwidth and timeslot calculation for the next cycle. The OLT generates the *GATE* message with the timeslot identified by granting values, such as starting time, time length, and wavelength, calculated by the DWBA; the granting wavelength for P2P traffic uses λ_{p2p} for P2P transmission. Further, the OLT broadcasts the *GATE* message to all ONUs, and the received *GATE* message at the ONU is parsed and demultiplexed to the ONU GATE processing, which is responsible for permitting the transmission within the timeslot assigned by the OLT.

Table I. Traffic Profile

	Scenario	EF	AF	BE	P2P
IPACT	5:60:35	5%	60%	35%	-
	5:50:45	5%	50%	45%	-
	5:40:55	5%	40%	55%	-
P2P-DBA	S1 - 5:60:35 (10%)	5%	60%	31.5%	3.5%
	S2 - 5:50:45 (10%)	5%	50%	40.5%	4.5%
	S3 - 5:40:55 (10%)	5%	40%	49.5%	5.5%
	S4 - 5:60:35 (20%)	5%	60%	28.0%	7.0%
	S5 - 5:50:45 (20%)	5%	50%	36.0%	9.0%
	S6 - 5:40:55 (20%)	5%	40%	44.0%	11.0%

III. PERFORMANCE EVALUATION

In this section, we compare the system performance of the proposed scheme with the IPACT scheme [12], in terms of the EF, AF, P2P, and BE packet delays, jitter, system throughput, and dropping. The system model is set up in the OPNET simulator with one OLT and 64 ONUs. The downstream and upstream channels are set to 4 Gbps, the distance from the ONUs to the OLT is assumed to be 10–20 km, and each ONU has a finite buffer of 10 Mb. In the extensively studied traffic model, most networks are characterized as self-similar and long-range dependent, and are utilized to generate high-burst BE and AF traffic classes with a Hurst parameter of 0.7; the AF and BE packet sizes are uniformly distributed between 512 and 12144 bytes, the P2P packet size, *i*, is uniformly distributed between 9600 and 12144 bytes, and the EF packet size is constantly distributed with 560 bytes. For the traffic profile shown in Table I.

A. Mean packet Delay

The simulation results for the EF delay demonstrate that our proposed scheme has better performance for the EF traffic, compared to the IPACT (without P2P traffic) for 1.0 ms and 1.5 ms cycle times, respectively. As shown in Fig. 3, the P2P traffic in scenarios S4–S6 perform marginally better than in scenarios S1–S3 for a 1.0 ms cycle time. For a 1.5 ms cycle time, it is clear that the P2P delay in scenarios S4–S6 outperforms that in S1–S3. In scenarios S1 and S4, for a 1.0 ms cycle time and traffic load of 70–100%, the P2P delay suddenly increases to more than 5 ms because the AF traffic (60%) is higher than those in the other scenarios.

B. Jitter

Figure 4 shows that for scenarios 1 and 4 at 1.0 ms cycle time and the traffic load of 70–100%, the P2P traffic jitter increases suddenly to more than 0.5 ms because the AF traffic (60%) is higher than those in other scenarios, causing the remaining AF, P2P and BE traffics be sent in the next cycle. When the cycle time is 1.5 ms, this problem will be alleviated because the timeslot provided by OLT is sufficient to send all the AF traffic; if there are remaining timeslots, they will be offered to P2P and BE traffic.

C. System Throughput

Figure 5 compares the system throughput between the proposed P2P-DWBA and the IPACT for different offered loads with different cycle times (1.0 ms and 1.5 ms, respectively). The results demonstrate that the system throughput of proposed P2P-DWBA is better than that of the original IPACT traffic for both cycle times; for the 1.0 ms cycle, improvement up to 4.7%, 6%, 7.4%, 9.4%, 12%, and 14.7% for S1–S6, respectively, can be achieved; whereas for the 1.5 ms cycle, improvement up to 4.2%, 5.5%, 6.7%, 8.5%, 11%, and 13.4% S1–S6, respectively, can be realized.

D. Traffic Dropping

Figure 6 shows the improved performance in the BE drop for both 1.0 ms and 1.5 ms cycle times. Simulation results demonstrate that BE traffic dropping can be reduced, when the P2P traffic ratio is higher (20% BE traffic), compared to that with a lower P2P traffic ratio (10% BE traffic). Comparing the 1.0 ms and 1.5 ms cycle times in S6 (5:40:44:11), it is obvious that the BE traffic dropping, at a cycle time of 1.0 ms, reduces up to 40%, and that at a cycle time of 1.5 ms reduces up to 58%. From our observation, we conclude that when the BE traffic ratio is smaller, BE traffic dropping will increase at all conditions (90–100%). This is because when the BE traffic ratio is smaller, the EF and AF traffic ratios are higher, causing the lower priority traffic (BE traffic) to be dropped to satisfy the higher priority traffic (EF and AF traffic).

IV. CONCLUSION

The proposed DWBA and SDN-controller can handle and enhance the required bandwidth for P2P service. Although our proposed scheme needs one extra wavelength for transmitting P2P traffic, it can guarantee the QoS by maintaining the traffic delay below 5 ms. It improved the BE packet delay up to 21%, throughput up to 13%, and dropping up to 58%, in scenario 6 (5:40:44:11) for a cycle time of 1.5 ms. We have enhanced the system performance of the P2P file-sharing application without consuming more resources; moreover, our proposed scheme can be further extended to be capable of handling other P2P applications, including P2P VoD, P2P IPTV, P2P live-streaming.

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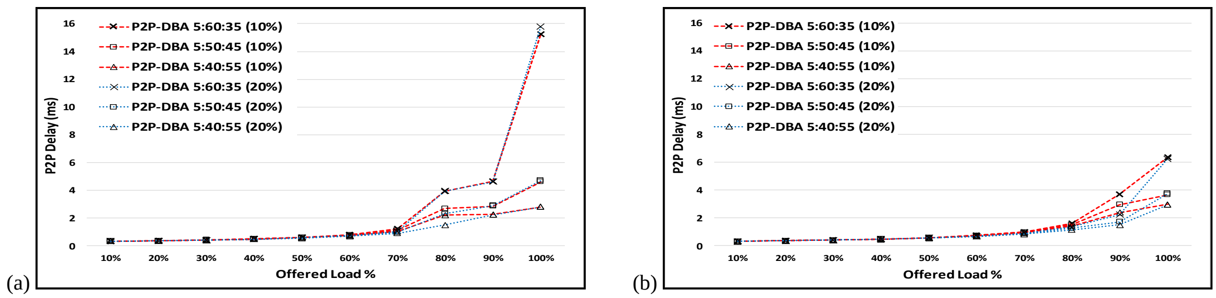

Fig. 3. P2P delay for (a) 1.0 ms cycle time (b) 1.5 ms cycle time.

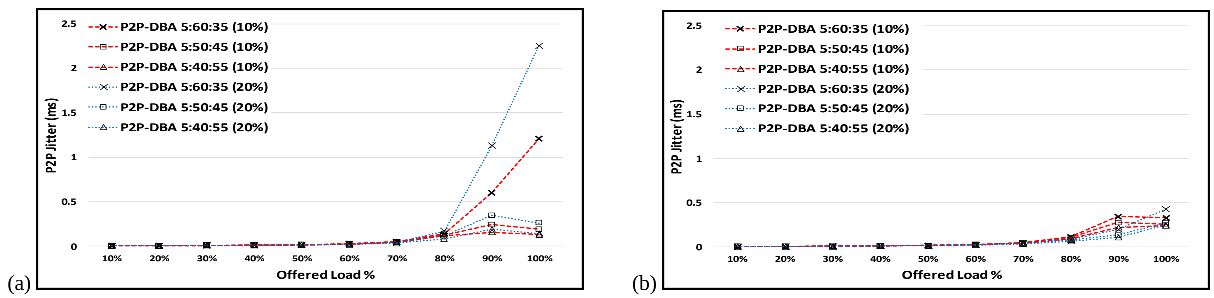

Fig. 4. P2P Jitter for (a) 1.0 ms cycle time (b) 1.5 ms cycle time.

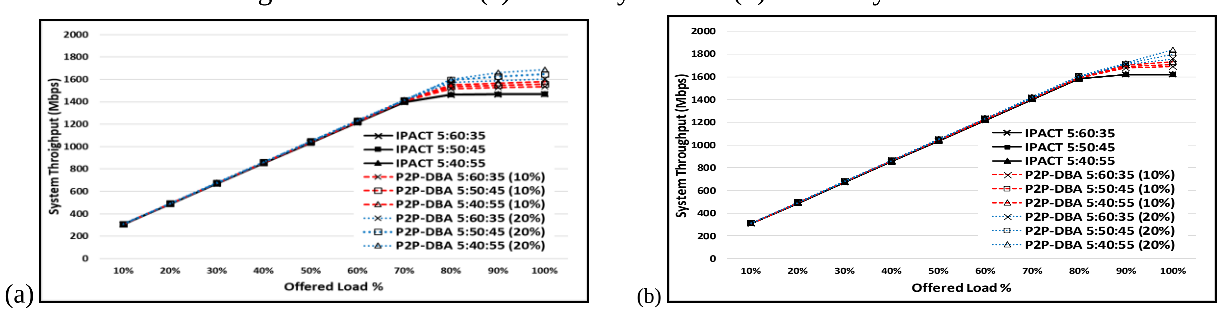

Fig. 5. System throughput for (a) 1.0 ms cycle time (b) 1.5 ms cycle time.

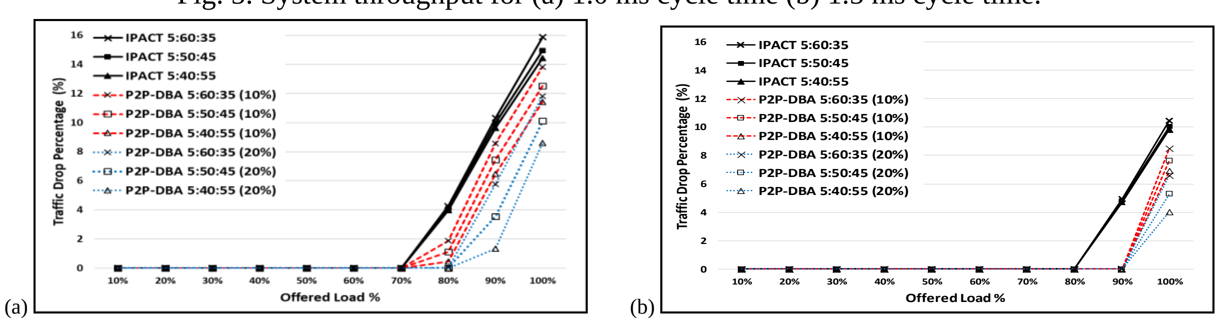

Fig. 6. Traffic dropping for (a) 1.0 ms cycle time (b) 1.5 ms cycle time.