IP service schemes for Ethernet PON and an EPON master chip designed to provide such services

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1. Introduction

EPON is considered to be one of the promising access network technologies and is being deployed in some countries like Korea and Japan. ETRI has developed an EPON chipset and this chipset is going to be used in a commercial trial service in the city of Gwang-joo, South Korea from early in 2006. The master chip, EPMC(EPON master controller), can connect up to 64 ONTs at the same time and provides two EPON ports providing higher port density for the OLT(Optical Line Termination) system located in the CO(central office). This paper defines four methods of IP(Internet Protocol) service schemes for EPON(Ethernet Passive Optical Network) and discusses their merits and limitations. It also briefly introduces the bridge function implemented in our EPON master chip which was designed to support the four schemes.

2. Ethernet PON protocol[1][2][3]

In EPON, to make the EPON compatible to the IEEE802.1D bridge operation, LLID(Logical Link ID) is used in the Ethernet preamble. Fig.1 shows the usage of the LLID in EPON. Every ONT is assigned an LLID value when it is discovered and registered by the OLT for communication through the OLT. The downstream LLID indicates the destination ONT and upstream LLID indicates source ONT. In PON, for any frame from an ONT to be delivered to another ONT, the frame should first be sent to the OLT and then the OLT should send the frame back to the PON interface, which is impossible in normal bridge. Normal bridge does not send a frame back to the port through which the frame was received assuming the frame should have been delivered through the LAN already. However, using LLID, the OLT can regard the PON interface as many logical links and can reflect the frame to the same physical interface like it is receiving a frame from a port and sending it to another port. The downstream LLID can represent broadcast or anti-LLID which indicates that the frame should be received by all ONTs except a specific ONT. Using broadcast LLID or anti-LLID, flooding can be implemented with single copy transmission effectively on the PON port.

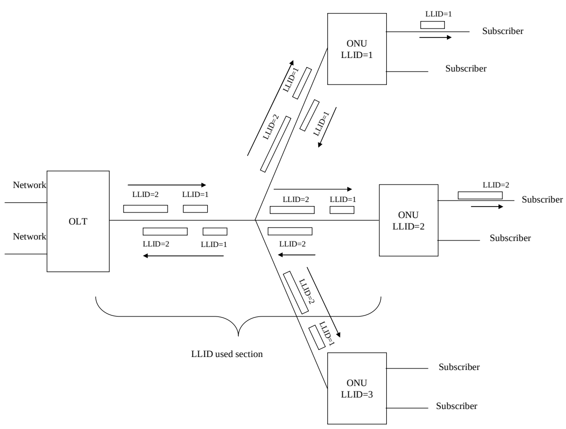

Fig.1 use of LLID in EPON

Another problem we would have without LLID is the source address learning problem at ONT. If a frame is received by an ONT from the user side and the frame goes up the PON and comes reflected down by the OLT, it will cause confusion in source address learning at the ONT because the source address learned from the user port will be learned from the PON port second time. Using LLID, the reflected frame can be discarded using LLID filter, and the frame is never seen second time at the originating ONT's bridge.

Using LLID solves all these problems and normal bridge operation is possible both at OLT and ONTs.

3. EPON IP service schemes

Today, network service is moving toward Ethernet based IP service and this is becoming a de-facto standard weather it's using Ethernet over ATM protocol(rfc1483) or dedicated Ethernet links[4]. In this paper, we assume the EPON master chip has internal bridge function and we use a switch which can perform either L2 bridging or L3 routing in the OLT system as shown in Fig. 2.

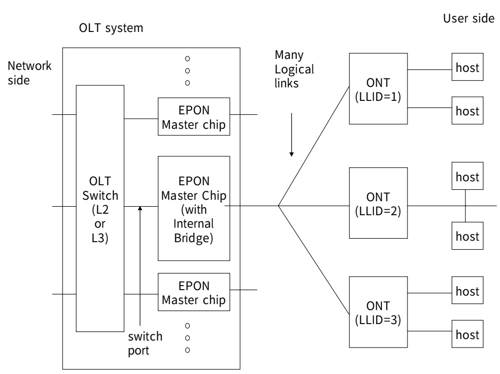

Fig.2 typical EPON network configuration

To provide IP service to the users using Ethernet PON transport, we can have several schemes of which 4 are identified and discussed below.

3.1 Pure L2 connection with ONT-to-ONT relay permission

The first and simplest method of providing EPON service is using pure MAC based bridging. In this method, For a PON link, the master chip acts as the L2 MAC bridge for the switch port and many logical ports in the PON. For all the frames entering master chip upstream and downstream, the source address is learned and destination port is looked up solely based on the destination MAC address so that the frame can be transmitted to the destination port. A frame sent by an ONT can be directly reflected to another ONT by the master chip. Appropriate LLID tagging occurs in case the destination is in PON direction. In the OLT switch above the EPON master chip, we can do either L2 bridging or L3 routing. The PON section constitutes a broadcast domain and all the hosts in the PON can be configured to be in the same IP subnet.

Since the OLT switch cannot see the traffic between ONTs, to provide IP service to the subscribers using this method, the PON bridge in the EPON master chip should perform many jobs including traffic management, tariffs and access control like NetBIOS or DHCP filtering. But since the separation of L2 connection between subscriber premises is a general requirement in access network[5], this scheme is not proper to use except in case the EPON link is installed for LAN application in single organization.

3.2 Pure L3 connection with ONT-to-ONT relay blocking

The second method is letting the PON bridge to do the upstream learning and downstream LLID tagging with ONT-to-ONT relay blocked. For two hosts in two different ONTs to communicate, they should communicate through router in the OLT system. Since bridges cannot send a frame back to its input port, IP packet should be sent to the router in the OLT and the packet should be sent to another ONT by the router. The MAC layer is terminated at the router.

For IP communication to occur, ARP request is sent to know the destination MAC address before sending the frame which is broadcast frame in L2. The destination host(when it's in the same LAN domain) or router(when it's in different LAN domain with different IP subnet) responds to this ARP request with its own MAC address so that the frame can be addressed to the proper station in the LAN domain.

For this IP routing scheme to work in EPON link, the OLT's switch should perform the proxy ARP function for communications between two hosts belonging to different ONTs. Normally, routers don't reply to the ARP request which is coming from a host in a subnet and looking for another host in the same sub-network[6]. But in this case, even though all the ONTs are in the same IP subnet, for some host pairs, they are not really in the MAC broadcast domain for different ONTs because ONT-to-ONT L2 forwarding is blocked. So the OLT should resume the task of routing among the hosts behind different ONTs. To this end, the router in the OLT switch should be able to discriminate an ARP between hosts belonging to two different ONTs and ARP between hosts belonging to a same ONT, for latter case it should not respond to the ARP request.

About the way how the proxy-ARP function discriminates ARP requests between different premises from those among a same premises, there is a well known technique called DHCP-snooping[5,8].

Proxy-ARP requires the knowledge of IP-LLID relationship for this type of operation. The DHCP server keeps the MAC and IP address relationship of the hosts and the EPON master chip can detect the LLID and MAC address relationship by snooping the DHCP communications. That is, by monitoring DHCP_DISCOVER or DHCP_REQUEST packets, the EPON master chip can extract MAC address and LLID relationship. Fig 3 shows how these two DHCP and DHCP snooping processes work together to provide necessary information for the proxy-ARP process.

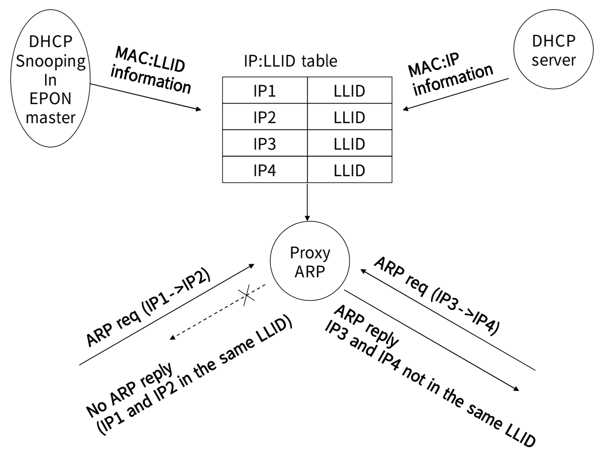

Fig.3 proxy ARP using DHCP snooping

The proxy ARP can be accomplished without using DHCP snooping. In this another method, the intra-premises ARP requests can be discarded or ignored before it reaches the access router function by observing upstream ARP requests and keeping the MAC-LLID information to distinguish and remove intra-ONT ARP requests.

Another trick is to wait until 3 ARP requests are coming and then replying since intra-premises ARP requests will be replied in 2 ARP requests normally.

3.3 VLAN routing in OLT switch with ONT-to-ONT blocking

Another viable, and protocol friendly method is using VLANs. In this scheme, the ONTs are set to different VLANs. This means that an ONT's user ports and PON port are configured to be a member set of a VLAN which are not shared by other ONTs. Since a VLAN defines a MAC broadcast domain, each ONT should be assigned an IP address with different IP subnet number. The OLT switch's PON interface is configured as the VLAN trunk port and the OLT switch should perform VLAN routing for the VLANs for the same PON interface.

This VLAN routing can be accomplished by tagging/detagging in ONT side or using EPON master chip's VLAN ID – LLID mapping function.

If we permit same VLANs to be assigned across multiple ONTs, we have to address the same problem of distinguishing intra-OLT and inter-ONT ARP processing in OLT switch as in the previous scheme.

3.4 Pure L2 connection with back-to-source function in the OLT switch

This scheme enables it to use L2 bridging in EPON master chip with ONT-to-ONT relay blocked. Since the OLT switch has back-to-source function(there is a commercial switch with this function), the frame sent up from an ONT can be reflected down by the OLT switch in case the DA is looked up to be located in the PON side. But when a reflected frame is sent downstream by the EPON master chip, a broadcast LLID can be attached due to FDB destination lookup failure, and this causes a frame sent upstream by an ONT being received downstream the second same by the ONT causing confusion in the source MAC address learning. This scheme cannot work correctly because of this problem.

4. The implemented EPON bridge functions

Together with the PON bridge function, the implemented master chip mentioned in the introduction provides for EPON control function called Multi-point MAC control. This function governs the auto-discovery of the ONTs and generates gate frames for the ONTs for the upstream bandwidth usage based on the report frames coming from the ONTs. Simple cycle based water-filling DBA algorithm was adopted and implemented[7].

Fig. 4 shows the block diagram of the master chip.

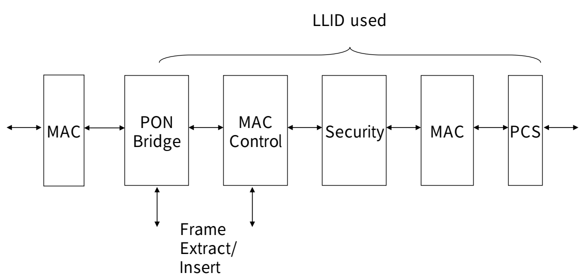

Fig. 4 EPMC block diagram (for 1 port)

The implemented PON bridge function supports pure L2 bridging for switch port and many logical links with optional ONT-to-ONT transport blocking and optional learning disable function for the downstream traffic. It also supports LLID-to-VLAN mapping so that VLAN routing can be used without tagging/detagging at ONTs. Tagging/detagging at ONTs is also supported. Fig. 5 shows the block diagram of the implemented PON bridge block.

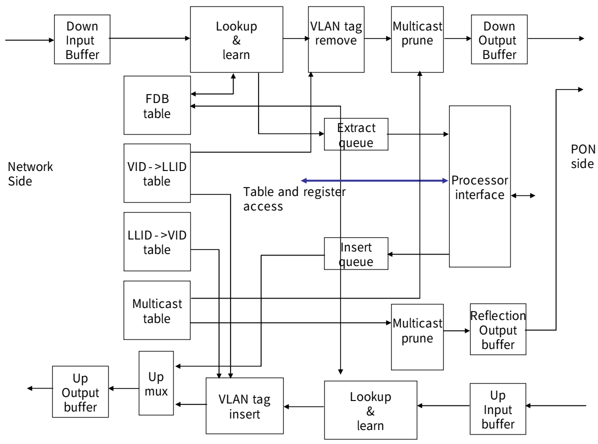

Fig. 5 PON bridge block diagram

The operation will be briefly explained. The downstream frame's DA is first looked up and VID->LLID translation is performed in VLAN mode. For multicast frame, the LLID can be overwritten according to the multicast address lookup result. For upstream frame, the DA is looked up and LLID->VID mapping is performed. For VIDs whose tagging/detagging is registered to be done at ONUs, VID-LLID translation is not performed.

Fig.6 shows the picture of the EPMC chip and the EPSC – slave chip.

Fig. 6 EPMC and EPSC chip

The implemented EPMC chip is expected to be used in the commercial trail service and BMT(Bench-mark test) was performed for systems using the developed chipset.

Through the tests, including full traffic conditions, it was shown that the bridge works properly in its address learning, lookup, forwarding and aging functions. The VLAN-LLID translation was not used because tagging/detagging was all done at the ONTs. For full traffic conditions, the bridge works properly. The DBA(Dynamic Bandwidth Allocation) function in the MAC Control block is shown to work properly providing over 80% line rate performance for 32 ONTs which is more than 680 Mbps in payload for 64 byte frames and bridge works properly for the maximum load of downstream 95% and upstream 80% line speed load. Over the maximum, frame loss occurs but the chip functions still properly.

5. Conclusion

There are choices in IP service schemes but to assign terminals at same IP subnets, or same VLANs, techniques to distinguish inter-ONT ARP from intra-ONT ARP should be considered. Though it can be managed by provision based methods, some general method should still be devised for this type of service strategies.

With developed EPON master chip, EPON service was successfully launched for trial service in Gwang-joo area early 2006.

The chip is going to be revised. The chipset is scheduled to be upgraded early in 2006 with bug fixes, performance and functional improvements.

<< References >>

1. "IEEE802.1D", 1998

2. "IEEE802.1Q", 2003
3. "IEEE802.3ah",2004
4. Susana Monteiro, "A New Access is Emerging", BMW2005, Whistler, BC, Canada, Oct.3-6,2005
5. T. Melson Erricson, "MAC-Forced Forwarding: A Method for Traffic Separation on an Ethernet Access Network", IETF internet draft, Oct. 2004.
6. John S. Quarterman, "RFC1027-Using ARP to Implement Transparent Subnet Gateways", IETF document, Oct. 1987
7. Chan Kim et. al, "Design and Implementation of an EPON DBA Algorithm", BMW2005, Whistler, BC, Canada,Oct.3-6,2005
8. R. Droms, "RFC2131-DHCP – Dynamic Host Configuration Protocol" IETF document, March 1997