Design and Implementation of an EPON Master Bridge Function in an ASIC

Chan Kim*, Tae-Whan Yoo, Yool Kwon, Bong-Tae Kim
Electronics and Telecommunications Research Institute
(ckim,twyoo,ykwon,bkim)@etri.re.kr*

Abstract

An EPON(Ethernet Passive Optical Network) master, slave chipset was developed. In EPON, LLID(Logical Link ID) value in the Ethernet frame's preamble is used to indicate the destination ONU(Optical Network Unit) in downstream and source ONU in upstream to make the PON look like a point-to-point links seen from the OLT(Optical Line Termination) and ONUs. This paper describes the function and implementation of an EPON bridge in the master chip which performs bridge function based on MAC(Media Access Control) address among the upper network port and many lower PON logical ports differentiated by LLID. This bridge also has VLAN(Virtual LAN)-LLID mapping function to make the PON appear as many VLANs seen from the network port. It is also possible to define many VLANs for each ONU. It also has multicast pruning function through which only registered multicast traffic is sent downstream to destined ONUs.

1. Introduction

EPON is an emerging access network technology widely accepted as providing high bandwidth at lower costs. Most papers related to EPON deal with DBA(Dynamic Bandwidth Allocation) but this paper describes the bridge function implemented in an EPON(Ethernet Passive Optical Network) master chip. The paper starts with a brief explanation of the general Ethernet bridging(switching) and EPON protocol. Then the design and implementation of the EPON bridge is explained. Finally, future work is briefly introduced.

2. Ethernet Bridge functions[1][2]

MAC(Media Access Control) bridges interconnect the stations attached to separate LAN(Local Area Network)s as if they were attached to a single physical medium. The MAC bridge is transparent to upper layers like LLC(Logical Link Control) or IP(Internet Protocol).

Ethernet frame contains DA(Destination Address) and SA(Source Address) at the head of the frame. When a frame is input from a port, it is learned that the SA exists in the direction of the input port and this information is kept in the FDB(Filtering Database). At the same time, the port information for the DA is looked up from the FDB and the frame is forwarded to the destination port. When the entry for DA is not in the FDB table, the bridge floods the frame to all ports except the input port to guarantee that the frame be delivered to the destination anyway. When the destination is believed to be in the input port, the frame is discarded.

This way, not knowing the physical locations of MAC addresses, the stations can communicate on the bridged LAN with each other using MAC addresses.

When certain MAC address is not observed in the SA field for a pre-defined time, the bridge deletes that old entry from the FDB table. Using this aging mechanism, FDB entries are quickly recovered and communication is instantly resumed after a brief flooding in case of physical location changes.

It is also possible to divide the bridged LAN into many virtual LANs. In a VLAN(Virtual LAN) aware bridge, frames belonging to a VLAN are delivered only to the ports having membership to the VLAN so that only stations in the same VLAN can communicate with each other. When broadcasting a frame, the bridge broadcasts the frame only to the VLAN member ports. VLAN is used to reduce the network load or to provide security among users of a LAN.

Ethernet frame may contain VLAN tag to indicate which VLAN it belongs to. When a frame is input without an explicit VLAN tag, VID(VLAN ID) is assigned to the frame using input rule. Usually, the VID is assigned to the frame according to the IP subnet, MAC address or protocol the frame contains but by the input port by default. When a frame is output to a VLAN member port, VLAN tag is attached or removed according to the corresponding VLAN untagged set configuration.

Usually, the VLAN tag is attached at the entrance of the network and detached when the frame leaves the network at the edge switch. VLAN is setup through provision and it can be manually set for each bridge or the VLAN setup information can be automatically spread throughout the bridges using GVRP(Generic VLAN registration Protocol). Through VLAN setup, the bridges know for each VLAN, to which port directions the VLAN member stations can be reached. A port can be the member port of many VLANs(VLAN trunk port).

3. Ethernet PON scheme[3]

EPON is a method of communicating in the PON(Passive Optical Network) topology using Ethernet frames. In EPON, OLT(Optical Line Termination) in the central office is connected to the residential area using single fiber and many ONU(Optical Network Unit)s or ONT(Optical Network Termination)s are connected to that fiber using passive optical splitter.

Existing bridges work only on the bus or star topology and don’t work in PON topology where downstream signal is broadcast to all ONUs but upstream signal goes only to the OLT. Normal bridge cannot reflect a frame received from PON port back to PON port. Also, if a frame sent upstream by an ONU gets reflected by OLT and received second time by the ONU, it would cause confusion in the source address learning at the ONU.

In EPON, to solve this compatibility problem, a value called LLID(Logical Link ID) is used in Ethernet frame preamble to make the PON appear as many point-to-point links seen from the bridges at OLT or ONUs. This LLID represents the destination ONU in the downstream and source ONU in the upstream. The LLID can also indicate that the frame should be broadcast to all ONUs, or the frame should be received by all ONUs except a particular ONU. Using this broadcast LLID or anti-LLID, operation like flooding in the bridge becomes possible over EPON.

LLID is assigned to the ONU by the OLT when the ONU is connected to the EPON through auto-discovery procedure. The discovery procedure and reporting, gating will not be explained here since it’s not relevant to bridge operation and they are shown in many literatures. Fig.1 shows how the LLID is used for point-to-point link emulation.

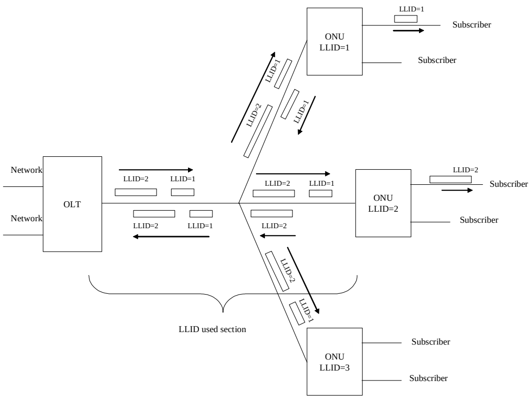

Fig. 1. Point-to-point link emulation using LLID

To avoid contention in the upstream direction, the OLT should arbitrate the upstream transmission of the ONUs allocating upstream bandwidth to ONUs in the mean time. Special queue report and grant mechanism is used based on synchronized timer. The implemented EPON master chip also performs the DBA operation which is explained in another paper[4].

4. EPON bridge function with VLAN and multicast support

This implementation adopts common FDB for upstream and downstream processing and accommodates peer-to-peer frame switching among ONUs. The bridging for upper network port and many lower logical link ports is equivalent to normal bridge for point to point network using advanced ULSLE(Upper Layer Shared LAN Emulation) first devised by Norman Finn from Cisco[5].

Here two simple EPON bridge modes of the chip are explained. The first mode called “MAC bridge mode” is for the PON bridge to act as a transparent MAC bridge for the upper network port and many logical links to the ONUs. It performs the MAC address learning for the SA and lookup for DA to forward the frame to either the network port or to the PON port with appropriate LLID values. This is to make the PON appear as a bridged LAN seen from outside. Fig. 2 shows the MAC bridge mode operation for many cases of destination address lookup.

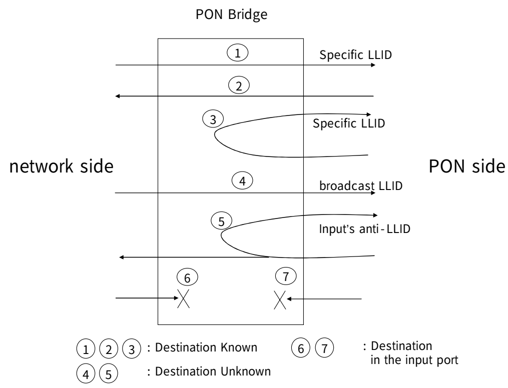

Fig. 2. MAC bridge mode(advanced ULSLE)

Second mode of the EPON bridge is called “VLAN-LLID mapping mode” and it is to provide a VLAN interface for each LLID to the network port. In the upstream, VLAN tag corresponding to the LLID is attached to the frame, and in the downstream, VLAN tag is converted to corresponding LLID through 1 to 1 mapping with tag removal. The PON appears as many VLANs differentiated by VIDs seen from the network port. In this case, the VLAN tagging/detagging is basically done by the OLT’s PON bridge allocating one VLAN for each ONU. However, it should be possible for some ONUs to have 2 or more VLANs. For these VLANs, tagging/detagging occurs at the ONU according to the protocol or port. OLT should pass the tagged frame intact in both direction, and downstream LLID is attached according to the VID. For VIDs which were registered in the VID-LLID mapping but not registered to have tagging/detagging at ONU, normal VID-LLID translation occurs.

Another important function of EPON master bridge is the multicast pruning capability. In IP, a host sends to all routers its intention to join or leave a multicast destination group. Also, routers query the hosts for membership information and hosts report their membership to the routers periodically. The joining, leaving, or report on membership is spread through the routers so that multicast traffic is delivered only to LAN segments with at least one member host for the multicast destination group. These operation is called IGMP(Internet Group Multicast Protocol). In many cases, commercial bridges in a LAN monitor the IGMP conversation between IP hosts and routers to filter multicast frames for output ports with no member for the multicast destination group. Also, for multicast pruning, bridges have their own protocol called GMRP(Generic Multicast Registration Protocol) for the same purpose in L2(layer 2 = MAC) level. IGMP and GMRP protocol processing is linked at the hosts.

The EPON master bridge is designed to snoop IGMP or GMRP protocol packets and to be able to filter multicast traffic that are not registered to have any member to receive it. Information on multicast registration is set up for each group at the bridge multicast table and multicast traffic with at least one member is delivered with appropriate LLIDs downstream. Since the LLID is 16 bit long, the value can represent 2^{16} values and many multicast groups can be defined using LLID. In case the EPON slave chip does not support multicast LLID, broadcast LLID may be used for multicast.

for cases where a multicast address could not be registered to the multicast table due to table size limit or it is known that a terminal attached at an ONU/ONT does not support IGMP, multicast should be passed down with broadcast LLID.

Fig. 3 shows the flow chart of LLID determination in the downstream. In VLAN mode, untagged frames or frames with unregistered VID are reported to the CPU through interrupt with filtering. Though not shown in the figure, for VIDs that are flagged to have tagging/detagging occur in the ONU side, VLAN tags are not removed or attached in the PON bridge.

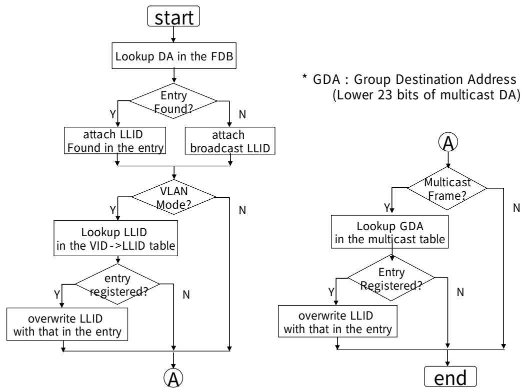

Fig. 3 Downstream LLID determination

5. Implementation of the PON bridge in EPON master chip

The developed master chip has internal PON bridge function with optional VLAN mapping and multicast pruning function. In this section, the implementation will be explained with some revised features added after chip fabrication. Fig. 4 shows the block diagram of the chip(CPU interface not shown). The MAC control block processes auto-discovery and upstream bandwidth allocation through MPCP(Multipoint Control Protocol). Frame extraction and insertion for the PON interface is done at MAC control block and those for network side port are done at PON bridge block.

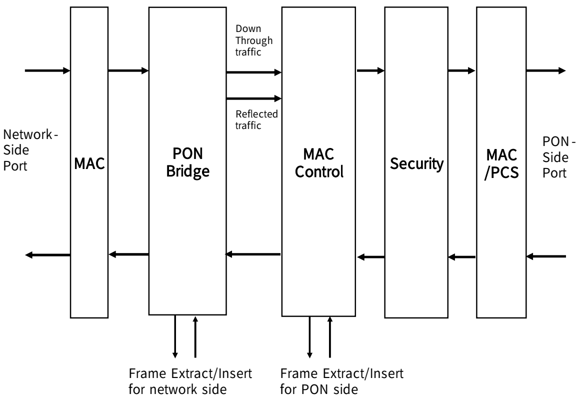

Fig. 4 Blocks of PON master chip

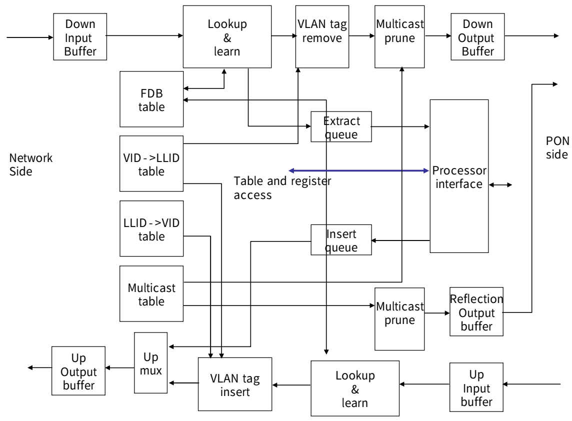

Fig. 5 Block diagram of PON bridge

Both MAC bridge mode and VLAN-LLID mapping mode are supported as explained before.

In MAC bridge mode, frames input from the network port are attached with LLID according to DA and delivered to PON interface and frames input from the PON port are either directed to PON side with a new destination LLID or delivered to the network port according to DA lookup result. Source MAC address is learned in any case.

In VLAN mode, frames are not delivered directly between ONUs and downstream LLID is attached by VID of the input frame and upstream VID is inserted according to input LLID of the frame. Tagging/detagging at ONU or multiple VLAN assignment to an ONU is supported. This is possible by having a flag at the VLAN table indicating tagging/detagging options for each VID.

Multicast address is registered in the multicast table through IGMP snooping or GMRP processing and only registered multicast frames are passed downstream. This multicast pruning is processed for programmed range in multicast MAC addresses. Fig. 5 shows the block diagram of the implemented PON bridge block.

Downstream lookup and learn block reads the frame from the downstream input buffer and attaches LLID according to the DA or VLAN tag. In VLAN mode, VLAN tag is removed but some tags are not removed. It also discards multicast frame with no member in PON side. In this PON bridge, downstream LLID is first determined by DA address according to FDB table, then LLID is overwritten by VID->LLID table when in VLAN mode, and overwritten by multicast table if the frame DA contains multicast address. For any case, the input SA and LLID is learned.

Upstream lookup and learn block reads the frame in the upstream input buffer and sends the frame to the upstream output buffer or reflection buffer with appropriate LLID addition or VLAN tag addition. If the DA location is not known, the frame is flooded to the network port and PON port with anti-LLID. In VLAN mode, for VIDs registered to have tagging at ONU, the tag is not changed. For reflected frames, multicast pruning is performed for unregistered destinations. For any case, the input SA and LLID is learned.

For cases when the content of the frame changes due to VLAN tag addition or removal, FCS should be re-calculated. The information on frame change is carried with the frame so that FCS is recalculated at the final output.

The FDB table contains the port information for MAC addresses. The entries are updated automatically by the learning process or written by the CPU. Each entry contains V bit indicating whether it's valid, S bit indicating static entry and A bit indicating the aging status. The A bit is set by the CPU with regular interval and reset by the learning process. If the A bit is remaining at the set value until the next processing by the CPU, the entry is removed by the CPU.

Hash operation using bit folding and CRC32 is used to map 48 bit MAC address to an FDB table entry location. To reduce the lookup or learning fail probability, address obtained by the hash operation and an associated address with pre-defined offset is used as a shared resource.

VID->LLID table has 4K entries for 12 bit VID value. Each entry contains the LLID value and a bit which indicates that the VID is to be tagged and detagged at the ONU side. This table is accessed both by downstream and upstream logic.

LLID->VID translation table contains 64 entries for 64 LLIDs and contains VLAN tag values for each LLID.

Multicast table contains 256 entries each containing registered multicast addresses and corresponding LLID. Lower 23 bits of the multicast MAC address is kept and to accommodate 223 possible addresses in 256 entries, hash mechanism is used with associative grouping.

6. VLAN considerations in EPON master bridge

Fig. 6 shows the possible VLAN configurations in EPON.

In the figure, ONU1 and ONU2 are members of VLAN12. ONU2 and ONU3 are members of VLAN23. At ONU2, if the frame input from the port belongs to certain protocol, VLAN23 is assigned and otherwise, VLAN12 is assigned. Similarly, ONU3's two user ports have ingress rule of assigning VLAN23 to frames carrying certain protocol with default VLAN VLAN31, VLAN32 for each port respectively. ONU4 assigns VLAN40 to its two user ports.

The designed PON bridge allows the case where tagging/detagging is done at the PON bridge for some VIDs while it is done at ONUs for other VIDs.

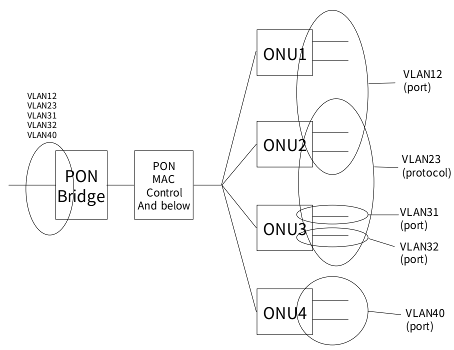

Fig. 6 Possible VLAN configurations in EPON

The complex case is when two or more ONUs can share a VID. In this case, the PON bridge should be able to forward frames between ONUs in the VLAN mode. For downstream traffic, if DA is looked up from the FDB, the specific LLID is attached. But otherwise, multicast LLID for that VID can be used if defined or just broadcast LLID can be used since ONUs/ONTs not belonging to the VLAN can discard the received frame using VLAN input filtering. For upstream traffic, if DA is known, the frame is either passed to the network port or reflected to an ONT with specific point-to-point LLID. Otherwise, the frame can be passed to the network port and reflected to the PON using anti-LLID. Input VLAN filtering is used for ONUs/ONTs not belonging to the VLAN.

These VID sharing among ONTs are not supported in the current design and will be incorporated in the next design. There once has been a proposal to define group ID in the LLID field so that flooding in the multicast group is possible[6]. But VLAN input filtering can solve the problem easily.

7. Conclusion

The implemented PON bridge in the master chip performs bridging among the network port and lower PON logical links. It provides MAC bridge mode and VLAN-LLID mapping mode with multicast filtering function.

Figure 7 shows the picture of the ASIC called EPMC(EPON Master Controller). The chip processes two PON ports and can control 64 ONUs/ONTs for each port. The chip was used in an EPON system and is going to be used in a service trial in the city of Gwang-joo for 750 EPON subscribers from early 2006 through Korea's two major telecom operator companies.

Fig. 7 Picture of EPMC ASIC

There is a plan to upgrade the chip in the near future by fixing bugs and improving functions and performance. In the PON bridge part, rate limiting/shaping using shared buffering and scheduling per flow is under consideration, the flow being defined by combination of LLID, VID, priority, etc.

References

[1] IEEE802.1D -1998 Standard

[2] IEEE802.1Q – 1998 Standard

[3] IEEE802.3ah – 2004 Standard

[4] "Design and Implementation of an EPON DBA Algorithm", Chan Kim et. al, 11th IEEE Bandwidth Management Workshop, Whistler, B.C. Canada, Oct.3-6, 2005.

[5] "Two Models for IEEE802.3ah EPONs", Norman Finn, IEEE802 document

[6] "Multicasting in EPON", Su-il Choi, IEEE802.3 plenary meeting, Orlando, Florida, Mar.2004.