Broadband PON-wireless Convergence Network based on Network Coding

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***Abstract* — The broadband PON-wireless Convergence based on Network Coding is a technology that increases in bandwidth efficiency at subscriber networks by applying the network coding to the PON-wireless system. In this case, a PON system accommodates increasing traffic at the stage of wireless access by using backhaul network. In this paper, we propose architecture of broadband PON-wireless convergence network based on network coding and describe technological advantage, applications, and expected effect by using this technology.**

***Keywords*— BcN, Passive Optical Networks, Network Coding, Wireless, FMC, Multicast, Wireless backhaul**

I. INTRODUCTION

Wireless-PON Convergence technology based on the network coding, in which the network coding is applied in wireless and PON (Passive Optical Network) converged network for accommodating the demanding wireless access traffic by utilizing the PON as a backhaul of wireless network, is extraordinary technology to augment the bandwidth efficiency of the subscriber network. With such a technology, it is possible to overcome restriction of wireless spectrum and organize next-generation optical and wireless converged network with cost effectiveness as we utilize the PON as a wireless backhaul. Moreover, adoption of network coding in that network improves the bandwidth efficiency and the network security.

By applying a network coding technology to the PON-wireless convergence network, it is expected that bandwidth efficient and secure wired/wireless convergence network can be realized, and thus high-quality and bandwidth-intensive services supporting QoS is economically provided to subscribers

The reminder of this paper is organized as follows. Section 2 presents basic PON technology as an access network and the network coding technology that improves bandwidth efficiency of PON-wireless convergence network. In Section 3, we introduce a broadband PON-wireless convergence architecture based on the network coding. Section 4 investigates achievable advantages and applications, and expected results by employing the proposed architecture and this technology. Section 5 discusses the future work and concludes the paper.

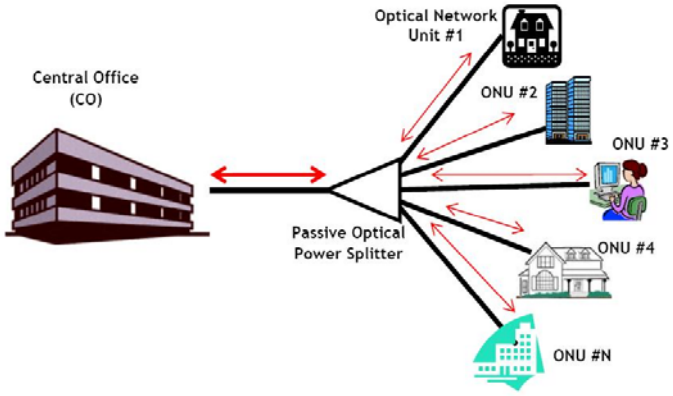

Figure 1. Architecture of a PON system

II. RELATED WORKS

In this section, we present the network coding technology that improves bandwidth efficiency of PON-wireless convergence network. Architecture of a PON System is shown in Figure 1. A passive optical network (PON) is a point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32. A PON consists of an Optical Line Termination (OLT) at the service provider's central office and a number of Optical Network Units (ONUs) near end users. A PON configuration reduces the amount of fiber and central office equipment required compared with point to point architectures. Downstream signals are broadcast to each premise sharing a fiber. Encryption is used to prevent eavesdropping. Upstream signals are combined using a multiple access protocol, invariably time division multiple access (TDMA). The OLTs range the ONUs in order to provide time slot assignments for upstream communication.

From the architecture of a PON, it can consist of an ONU-BS combined with ONU and Base Station, and each ONU-BS stage for wireless communication can be configured to certain cell. Mobile Set can send and receive a wireless IP traffic by ONU-BS.

Network coding means the number of packet information can be one packet from each node. So bandwidth efficiency can be improved. The concept of network coding introduced

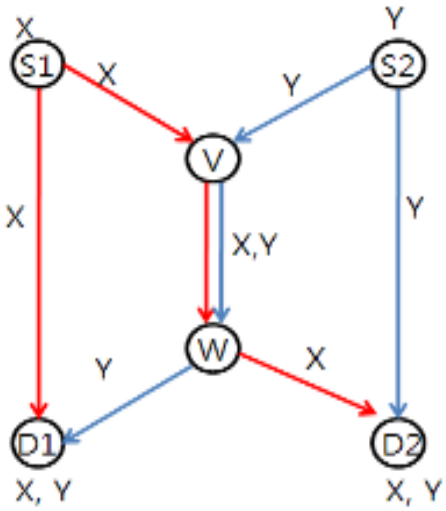

Figure 2. Existing multicast routing algorithm without network coding

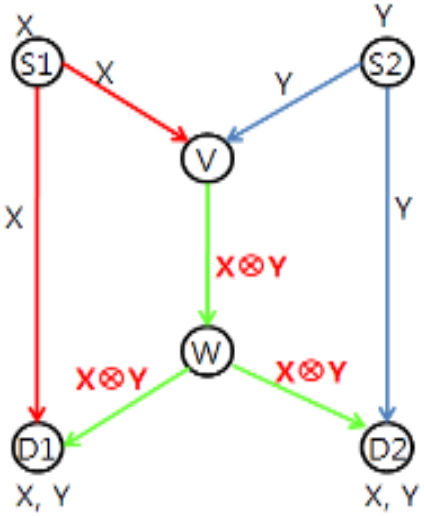

Figure 3. Multicast routing algorithm with network coding

R.W.Yeung and Z.Zhang's paper about Satellite Network, 1999. Especially, it can satisfy theoretical limit in the multicast circumstance. Therefore, it is becoming a viable technology where rapidly increase high speed multicasting broadcast service area.

The existing internet routing operates store information and pass through to the next node between network nodes, while the network node applied network coding combine information from more than two nodes and send to next node. i.e., the network coding allows combining information from each node different from the existing internet routing operation. The existing internet routing operates store information and pass through to the next node between network nodes, while the network node applied network coding combine information from more than two nodes and send to next node. i.e., the network coding allows combining information from each node different from the existing internet routing operation.

In the butterfly network, two source nodes S1 and S2 send information each X and Y to destination nodes D1 and D2. If we use existing multicast routing, then Node V and W be able to pass through X and Y, but not both, as shown Figure 2.

On the contrary, the case of multicast routing algorithm with network coding is shown in Figure 3. Because of two packets are combined into one at the coding node V and transmitted, the link between V and W utilizes only the bandwidth for transmitting one packet. In the other words, when we want to transmit two packets immediately at a link, the multicast applying the network coding is practicable to transmit two packets using merely one channel at a link while the typical multicast network needs two channels, thus saving the bandwidth. In case of figure 3, there are 2 data sources node and coding node V encodes just 2 packets, so the utilization of bandwidth is 200%. If we adjust network coding technology in multi-source nodes (more than 2 source node), that means if coding node encode more than 2 packets at one time, then the utilization of bandwidth can be more increased.

III. PON-Wireless Convergence Network Based on Network Coding

In this section, we introduce a broadband PON-wireless convergence architecture based on the network coding. It is a technology that expands stage of wireless access and accommodates wireless traffic by applying backhaul of a PON. So it can increase throughput in multicast traffic of wireless network by using network coding. We can take a advantage of increasing wireless backhaul network, utilization of link efficiency, reduction of the transmission time and enhanced security. It can be able to provide high quality service such as next generation IPTV services (Mobile IPTV, WiMAX IPTV and WiBro IPTV) economically.

Figure 4. shows the architecture of PON-wireless convergence network based on network coding. There are some advantages each technology of PON and wireless. A PON can provide broadband between 1 to 10G and maintenance cost is cheap. And network coding has a good bandwidth efficiency and security. Therefore the PON-wireless convergence network takes advantage of increasing wireless backhaul capacity and network extensibility (10~100km), integrated of existing wire/wireless network, and L2 handover process is easy between difference networks.

In propose architecture, OLT is coding node for network coding. Therefore, OLT combine several data packets to one encoded packet. The encoded packet is transmitted following optical link between OLT and optical splitter. At the optical splitter, the encoded packets are broadcasted to each ONUs. After that each ONUs receives the same encoded packets. Each ONUs cannot decode by using only received encoded packets. Each ONUs needs also another packet that has information to decode. For example, if OLT encode two packets P1 information packet and P2 information packet to one coding packet P1⊕P2, then each ONUs needs either P1 information of P2 information to decode P1⊕P2 coding packets. We have to assume that each ONUs can receive P1 or P2 packets from any other ways. It is possible because of

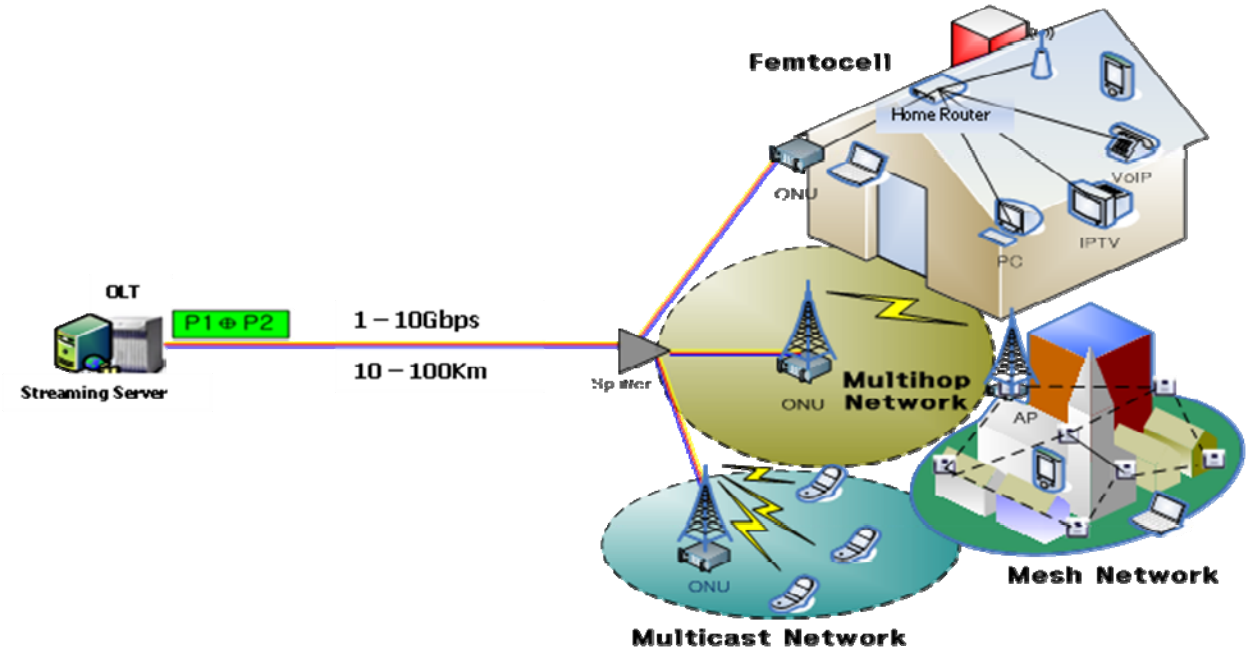

Figure 4. Architecture of PON-wireless convergence network based on network coding

ONUs are connected with other different networks and there are infinite probability to receive P1 or P2 information from any other nodes at the future networks. In the reference paper [1], advanced PON system is introduced and it is possible to communicate between each ONUs directly by using local access network. In this case, the probability to receive P1 or P2 information from any other connected ONUs is very large. In addition, Dr. R.W. Yeung said we have to consider the decoding probability of receiver node is almost more than 98% at the future networks.

This proposed architecture has more good performance at multicast services. As mentioned at section 2, network coding is very strong aspect to multicast services. The detail method to multicast algorithm will be announced at the future works. In this paper, we just introduce network coding technology and PON-wireless convergence network and then propose combined two technologies to broadband PON-wireless convergence network based on network coding.

IV. Technical Expectations and Applications

In this section 4, we will discuss about expectations and applications of wireless-PON convergence technology utilizing network coding technically.

A. Technical Expectations

1) ***Support stable wireless IPTV services:*** As wireless traffic increase rapidly, wireless communication system needs huge backhaul network. A PON system can be a one of solution of that because of PON system can support terabit data transmission economically. In addition, we use network coding technology to maximize utilization of transmission rate. Therefore, we can support variable high quality wireless IPTV services stably by using network coding based PON-wireless network to backhaul network.

2) ***Enhance the network performance:*** As we mentioned before, network coding technology is very good to multicast communication. In multicast transmission, OLT do the network coding for multicast traffic. And then the network coded traffic is transmitted by some specific wavelength between OLT and ONUs. Then ONUs can receive network coded traffic and do decoding process. ONUs can increase the decoding probability due to use of optical carrier link. In addition, PON-wireless link can enhance the utilization of link, deduction of transmission time, security of information by using network coding between OLT and ONUs

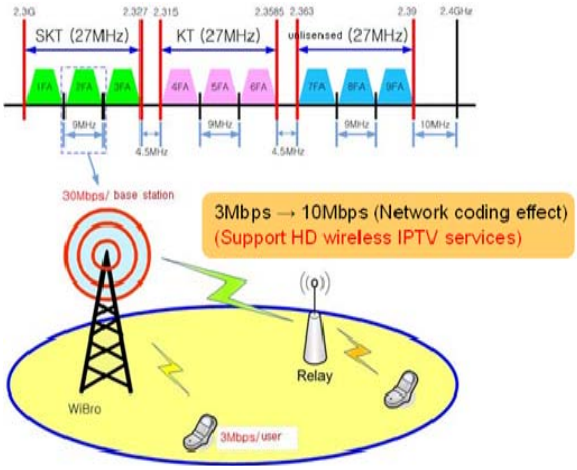

Figure 5. Effect of network coding to adjust WiBro system.

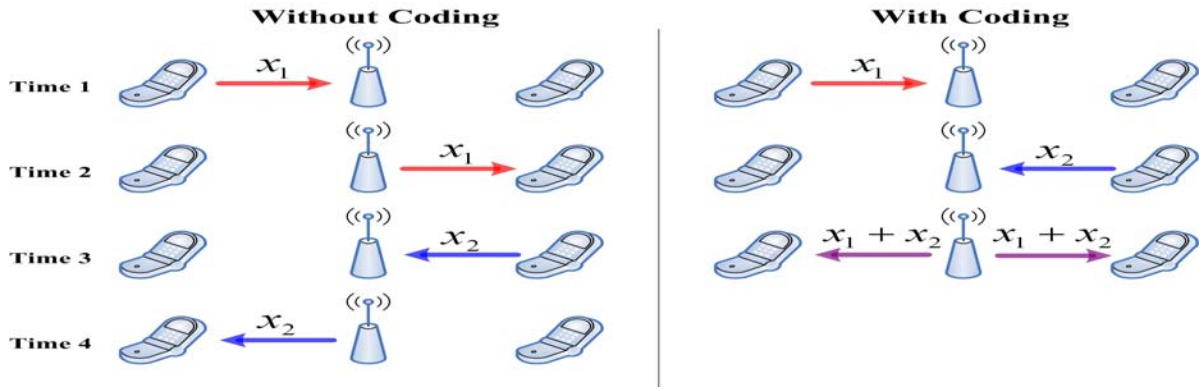

Figure 6. Comparison of without network coding and with network coding in bi-directional relay transmission.

3) ***Overcome of wireless spectrum limitation:*** If we use network coding to wireless network, then we can transmit huge data traffic even though we use small wireless spectrum. The wireless spectrum is limited, and it is not enough to support high quality wireless services at future. For example, currently the bandwidth per one WiBro user is 3 Mbps, and this is not enough to support HD wireless IPTV services. HD wireless IPTV service needs 10 Mbps transmission rate. However, if we use network coding technology to WiBro system, then it is possible to support around 10 Mbps per one WiBro user when network coding performance has 300% bandwidth utilization. Figure 5. shows effect of network coding to adjust WiBro system.

4) ***Solution for the network security problem:*** In the network environments, security problems can be categorized by 2 kinds of attacks; active attack and passive attack. The active attack pattern is almost message modification and retransmission and passive attack pattern is almost bugging the messages. If we use network coding for information transmission, the receiver only can decode the original information when satisfy some specific condition; network coding metrics or network coding key. However, eavesdropper cannot decode the original information because of eavesdropper doesn't know some specific condition. Therefore, network security by using network coding technology is more efficient and economical solution compare to existing routing security solution.

B. Technical Applications

1) ***Bi-directional relay transmission:*** In wireless network, bi-directional relay network is one of important network. In wireless relay network, bi-directional relay node can handle only one transmission process at specific time. So, if we want to transmit 2 data traffic, relay node needs 4 specific times. However, if we use network coding at relay node, we need only 3 specific times for transmission of 2 data traffic. That means 1 transmission time is reduced. The reduction of transmission time means increase of bandwidth utilization. Figure 6., the left side shows process of bi-directional relay transmission without network coding and the right side shows process of bi-directional relay transmission with network coding. If we use network coding to multi-hop bi-directional relay transmission, the bandwidth utilization can be more increased.

2) ***Re-transmission with network coding for recover:*** As mentioned bi-directional relay transmission process in upper application 1), relay node can transmit only one data traffic at specific time I. If receiver node do not receive some data packet due to the data loss, then the relay node have to re-transmit the loss data packet. In below figure 7 shows re-transmission process with network coding for recover loss packets. All receiver nodes A, B, C want to receive packet P1, P2, P3. However, receiver node A and receiver node B don't receive P2, P3 respectively. So, relay node have to re-transmit P2 and P3 to node A and node B respectively. In this re-transmission process, relay node need 2 specific times to re-transmit P2 and P3 to node A and node B respectively for recover. For reduce the retransmission time, relay node encode P1, P2, and P3 by using network coding, and then re-transmit network coded data packet P1⊕P2⊕P3 to all receiver node at one specific time. Therefore, re-transmission with network coding is more efficiency to recover loss packets.

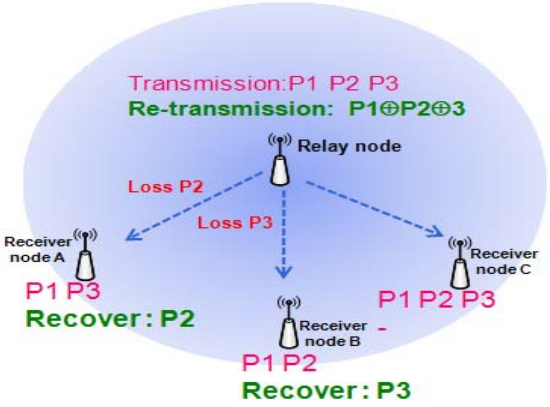

Figure 7. Re-transmission process with network coding.

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we are look the broadband PON-wireless convergence network based on network coding technology. PON-wireless convergence network system is absolutely one of strong solution as a wireless backhaul network to support broadband wireless services. In addition, network coding technology is also very strong aspect in bandwidth utilization and multicast services. We believe the combined technologies between PON-wireless convergence network and network coding technology can support huge broadband services such as HD wireless IPTV services with high QoS at future BcN network. In this paper, we propose the PON-wireless convergence network architecture based on network coding and discuss about technical expectation and applications of this technology.

For future work, we will research and develop more detail and particular technologies and adjust other technical areas within proposed convergence network. For more, we will need simulation and implementation of this technology at future works.

ACKNOWLEDGMENT

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