An Efficient MAC Scheme with Modified RTS/CTS of IEEE P1901

Jae Yong Park[1], Choong Seon Hong[2], Sungwon Lee[3]
Department of Computer Engineering, Kyung Hee University,
1 Seocheon, Giheung, Yongin, Gyeonggi, 449-701, Korea
[1]jypark@networking.khu.ac.kr, [2]cshong@khu.ac.kr, [3]drsungwon@khu.ac.kr

***Abstract*— According to multimedia service distribution such as High-Definition Television (HDTV), Internet Protocol Television (IPTV) and Voice Over Internet Protocol (VoIP), the networks are required to guarantee Quality of Service (QoS) and real-time performance. Power Line Communication Technology is used for data transfer as well as the transfer of electric power. However, power line communication has some problems in wireless communication such as a noise and hidden station problem. And MAC cycle is synchronized with AC cycle of power line. MAC scheme is week in real time data transmission with short cycle. Therefore, in this paper, we propose a new MAC scheme for real-time service. Proposed scheme uses new message called TRINFO. It has scheduling information and is added to the RTS/CTS message. And we divide MAC cycle between time slot request region and data transmission region. Finally, there is a simulation with MAC performance of IEEE P1901 standard and the proposed MAC. Simulation result shows that a proposed scheme outperforms existing standards from the viewpoints of jitter and delay.**

Keywords- PLC MAC, Power Line Communication, IEEE P1901, VoIP, Multimedia, CSMA/CA, TDMA

I. INTRODUCTION

There are several ways to use broadband communications in the building; however, it is still experiencing problems. Any device that requires power is supplied from power lines. Thus, for power line communications, networks have already been built. Before 2005, the PLC was individually develop by different organization. However after that period IEEE regrouped all the ideas for PLC standardization called IEEE P1901. [1,2]

The ongoing standard IEEE P1901 uses the AC power lines to develop a standard for high-speed (faster then 100Mpbs) communication devices at Physical layer (PHY). This device called the Broadband Power Line (BPL) device uses frequency below 100MHZ. The standard assumes that any device will communicate within 1500m. They provide broadband services, and other transmission technology such as LAN which has been applied in buildings and can be used separately. Because BPL devices share the same media, IEEE P1901 standard focus on balance between BPL devices (for use of PLC channels effectively) and detailed mechanism which is defined for interoperability with other BPL devices. And It was designed to ensure sufficient bandwidth and QoS. This standard defines the physical layer and the medium access sub-layer of the data link layer, as defined by the International Organization Standardization (ISO), the Open Systems Interconnection and the (OSI) Basic Reference Model.

VoIP of multimedia services is real-time service and makes regularly packets for user's voice transmission. It is important to know how fast and regular packets arrived at their destination. Furthermore, Transit delay and Jitter are the core qualities of service, because users can easily recognize this when they talk.

In this paper, we discuss the availability of multimedia services through power lines. In the next section, background and related works will be provided followed by the evaluation of IEEE P1901 MAC standard using PLC for providing multimedia services. Then we outline the current problem and propose a new MAC scheme to improve the delay. Before concluding our work, simulation results will be presented and analyzed.

II. RELATED WORKS

First, we introduce the concept of power line communication. IEEE 1901 is based on the beacon and uses a periodic channel access mechanism. Beacon periodic has close relationships with the frequency of AC Line.

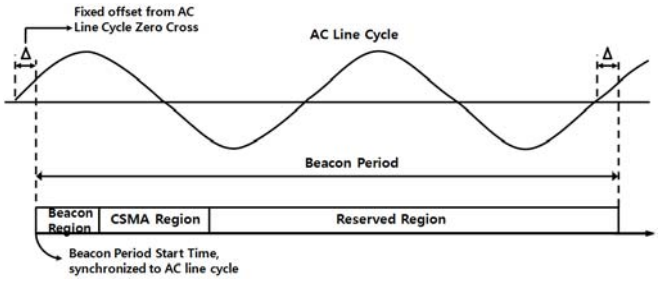


Figure 1. AC cycle synchronization of the Beacon Period

P1901 MAC has two modulation types at PHY layer called FFT and Wavelet. FFT MAC is synchronized with AC period cycle, 50Hz or 60Hz.

IEEE P1901 MAC scheme is based on CSMA / CA scheme and the TDMA-based structure. CSMA/CA (Carrier Sense Multiple Access With Collision Avoidance) uses a wireless

network multiple access method. Collision avoidance is used to improve CSMA performance by not allowing wireless transmission of a node if another node is transmitting; thus, reducing the probability of collision due to the use of a random truncated binary exponential back-off time. And RTS/CTS exchange can be required to better handle situations such as the hidden node problem. TDMA (Time division multiple access) is another channel access method for shared medium networks and it allows several users to share the same frequency channel by dividing the signal into different time slots. The user transmit in rapid succession, one after the other, each using his own time slot.

Power line communication is wired network, but there are many features similar to wireless.

A. Beacon Region

Beacon region is located at first in the MAC structure. And it has the scheduling information of following CSMA Region and Reserved Region, STA link information, and authentication information. Beacon uses many slots at least 1 to 8 (MaxBeaconSlot). So, the total length for beacon region is sum of Beacon-to-Beacon Inter Frame Space (B2BIFS) and PPDUs. Beacon field is composed of 16 octets and each BIBIFS length is defined as 90usec±0.5usec.

TABLE I. INTER FRAME SPACE(IFS) VALUE

Parameter	*Value*
Allocation Interframe Spacing (AIFS)	*30 usec*
AllocationTimeUnit	*10.24 usec*
Beacon To Beacon Interframe Spacing (B2BIFS)	*90 usec ±0.5 usec*
Burst Interframe Spacing (BIFS)	*20 ±0.5 usec*
CIFS_AV	*100 ±0.5 usec*
Default Maximum MSDU Size	*1522 octets*
EIFS_AV	*2920.64 ±5.0 usec*
MaxBeaconSlot	*8*
MaxFL_AV	*2501.12 usec ⩽MaxFL_AV ⩽ 5241.6 usec*
MinCSMARegion	*1500 usec*
Priority Resolution Slot (PRS)	*35.84 ±0.5 usec*
RIFS_AV_default	*140 ±0.5 usec*
Slot Time	*35.84 ±0.5 usec*

B. CSMA Region

CSMA Region uses competition transmission and it has PRS0 and PRS1 to give higher priority, each PRS is 35.84us. Contention Window (CW) is assigned per 35.84us, variable exists in up to 7~63.

In CSMA Mode, MPDU Payload is capable of generating as much as the FL_AV, FL_AV length is at least 2501.12usec and up to 5241.6usec. After the MPDU transmission, short RIFS exist before response using acknowledge frame. And CIFS exist before next Contention Window.

C. Reserved Region

STA transmit the MPDU using a predetermined schedule information in Reserved Region. BM determines the transmission schedule of all STA in BBS, and sends this information to STA using Beacon frame according to the beacon cycle. Each region time is 1.28usec multiples.

If there are streams that require QoS, and the BM is capable of QoS management, there may be allocations for specific streams in the Reserved Regions.

D. MAC Frame Fragmentation and MPDU Generation

Figure 2 shows the MAC frame fragmentation and MPDU generation. MAC frame is variable length, aggregated by the same destination. To segmentation, padding will be added at the end. Segment length is 512 octets. By add the padding, MAC frame stream should be a multiple of 512 octets. Each segment is encrypted by using a unit of transmission at PHY layer, and a unit of ARQ. The PHY block is composed of the PB Hdr(Phy Block header), PBB(Phy Block Body) and the PBCS.

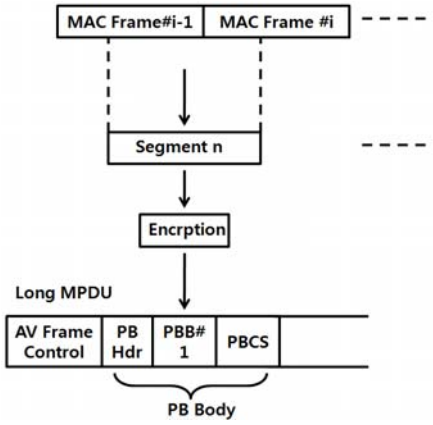


Figure 2. MAC Frame Fragmentation and MPDU Generation

The information contained in the frame control field and PB header is used by the receiver to determine uniquely the stream to which a segment belongs. The relevant fields in the frame control are STEI, DTEI, MCF, LID. When the Multicast Flag(MCF) field indicates the presence of a broadcast /multicast payload, the DTEI is assumed to be 0xFF for reassembly purpose.

There are two ways of MPDU transmission. Figure 3(A) shows general transmission method. SOF is an abbreviation for the start of frame, MPDU are transmitted in this duration. If successful reception, receiver replies with an acknowledgement frame (ACK) after RIFS. After waiting as long as CIFS, the next transfer begins. Figure 3(B) shows MPDU burst mode. Multiple MPDU packets are sent consecutively, receiver replies with SACK(selective ACK) that indicates the MPDU packet was successful or failed. It can not stay out in the middle of the transfer to the other, it uses the short inter-frame space; BIFS. Burst Mode is suitable for sending large data.

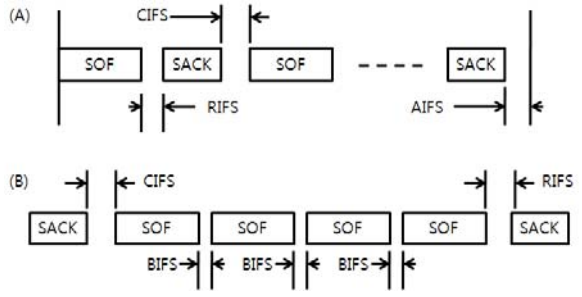


Figure 3. Inter-frame Spacing and MPDU Bursting

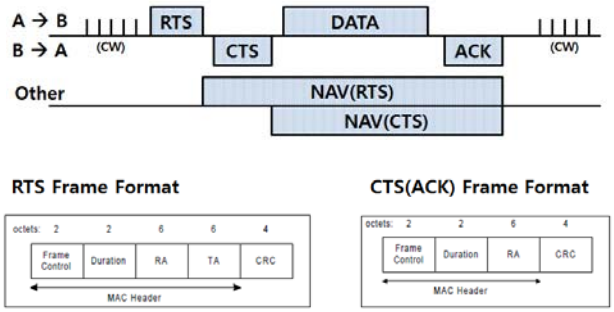


Figure 4. RTS/CTS Scheme and frame format

E. RTS/CTS Multiple Access Scheme

Figure 4 shows RTS/CTS multiple access scheme and RTS, CTS frame format. A station willing to transmit a packet will first transmit a short control packet called RTS (Request To Send), which will include the source, destination, and the duration of the following transaction (i.e. the packet and the respective ACK). The destination station will respond (if the medium is free) with a response control packet called CTS (Clear to Send), which will include the same duration information. All stations receiving either the RTS and/or the CTS, will set their VCS(Virtual Carrier Sense) indicator (called NAV, for Network Allocation Vector) for the given duration, and will use this information together with the physical carrier sense when sensing the medium.

III. PROBLEM DEFINITION AND PROPOSE SCHEME

VoIP uses an interactive service more than other multimedia services in home network. Users feel service quality directly, especially when quality of service goes down by an increase of the transmission delay. VoIP requires only 32kbps of bandwidth and this bandwidth requirement is lower than other services. But it generates fixed size packet streams in a short period(every 20ms). In related works, we introduce that PLC MAC cycle is synchronized with AC 2 cycles. For this reason, MAC cycle repeat every 33ms when using 60Hz frequency, and the sender can send again only after that period. Thus, transmission cycle is about 1.5 times longer than the generation cycle. This difference increases the delay of packet and makes jitter value not uniform. Hence, Packet stream can not arrive on time and service quality degrades.

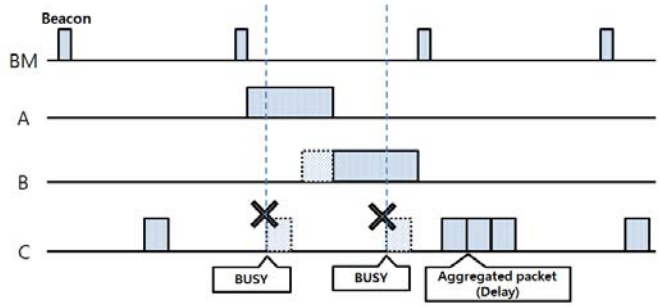


Figure 5. Problem scenario in CSMA only mode

This figure 5 shows the problem specifically. There are 3 senders in network, we used CSMA only mode for transmission scheme. It does not consider the other receiver to simplify in this figure. STA A and B generate long MPDU. STA C is VoIP station, it makes voice captured packet periodically. STA A sends a long MPDU and STA B sends a MPDU after STA A. At that time, STA C can't send MPDU on time. C should send its own packet after STA A and B. The MPDU aren't lost, but failed to deliver in real-time.

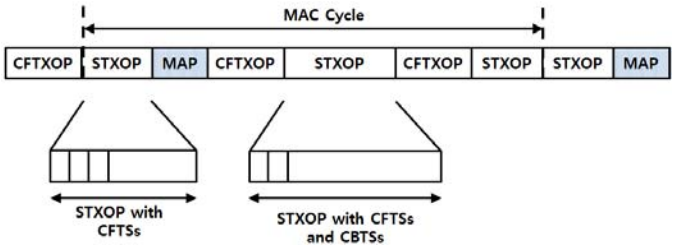
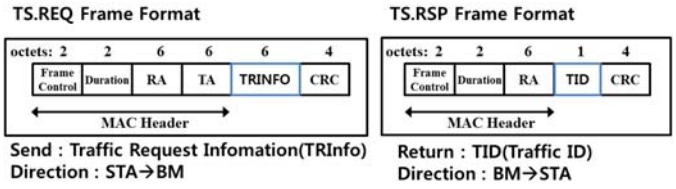


Figure 6. G.9961 MAC cycle and MAP message

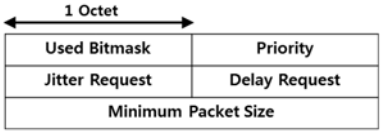
G.9961 standard of ITU-T divides many slots and uses Contention-free TXOP(CFTXOP), Shared TXOP(STXOP). STXOP consists of CFTS(Contention Free time slot) and CBTS(Contention Based Time Slot). Scheduling information is stored in the MAP message. It is an efficient mechanism but necessary to analyze the large amount of computation to scheduling.

In this paper, we propose enhanced RTS/CTS scheme for multimedia service devices that generates packets periodically such as VoIP. Scheduling information is added to the RTS/CTS packet. More accurately, we define a scheduling information message called TRINFO that is only 6 octets and insert it in the RTS packet. It is a very short message type, so it does not make large overhead than original RTS messages. Figure 7(B) shows a specific message type. TRINFO message includes priority, jitter request, delay request, and minimum packet size for allocation slots of reserved region. Bitmask is used to indicate presence request fields. In original RTS/CTS scheme, a station willing to transmit a packet will first transmit a RTS, the destination station will respond with CTS, then transmission will begin immediately. But proposed scheme, shows in figure 7(C), RTS/CTS packet exchange in CSMA region but does not send data packet after receive the CTS packet. We uses CSMA region for RTS/CTS packet to schedule reservation and

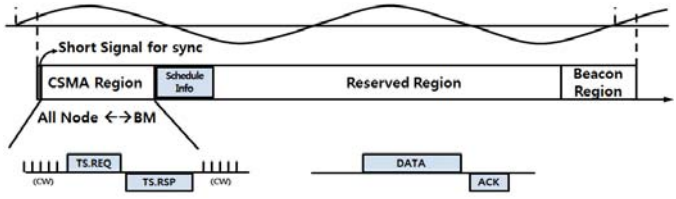
reserved region operates TDMA(Time division multiple access) scheme. In the first part of reserved region, BM transfers schedule information to all stations, and many slots use to communicate with each other according to schedule. Scheduling plan can change by scheduler although RTS/CTS packet is exchanged.



(A) Proposed RTS, CTS Packet



(B) Traffic Request Information(TRINFO) message



(C) Proposed RTS/CTS Scheme

Figure 7. Proposed Message and Scheme

Figure 7(C) shows proposed scheme. All stations are synchronized with the ac cycle of power line. Original P1901 scheme synchronized by beacon message, proposed scheme uses short signal for synchronize. This signal message is only used for synchronization without any information of network. RTS/CTS message exchange in CSMA region that uses contention based method. Even if sender receives the CTS packet, will not transfer until it receives the scheduling information in the reserved region. The actual transfer is done in the reserved region. Scheduling information is located at first in the reserved region. All stations should communicate following schedule with contention-free. BM sends link-information, authentication-information, network statement, region time information of next cycle and other data for manage the network, except scheduling information at beacon region. And CSMA region, reserved region and beacon region change their position when it needs to support QoS in proposed scheme. If transmission time that has already been reserved is expected to overlap with CSMA region or beacon region, then BM should move their next position, shown in figure 8. Beacon message in MAC cycle n has information of MAC cycle n+1 position about CSMA region, Reserved region and beacon region. In the same way, beacon message in MAC cycle n-1 defines each region position of MAC cycle n.

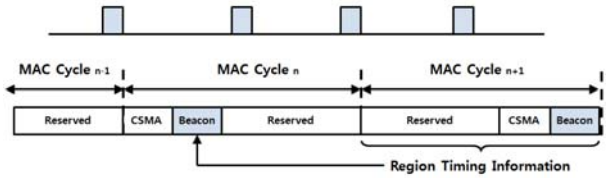


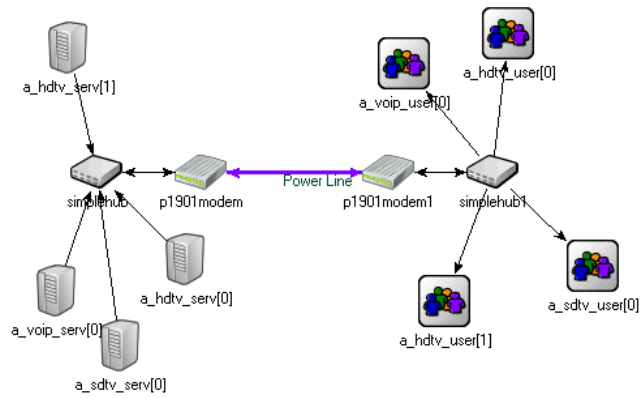
Figure 8. Example of proposed scheme

IV. SIMULATION

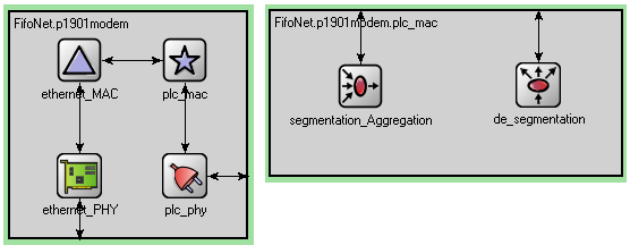
In this chapter, we simulate IEEE P1901 standard and proposed MAC scheme through Omnet++ simulator. Packets that are small and short interval have high priority when it overlap. We simulated home network environment as test scenarios. Increasing the digital broadcasting service, increased the premises to use the contents without extra lines in home. There are 2 HDTVs, 1 SDTV as CCTV and VoIP. The packet characteristics are summarized in Table 2. Figure 9(A) shows network topology for simulation. Modem modules for MAC scheme is shown figure 9(B). It has two interfaces that PLC line and Ethernet line.

TABLE II. DEFINITION OF MULTIMEDIA SERVICE PACKET

Service	Bandwidth	Period	Payload
HDTV	20Mbps	1ms	2500byte
SDTV	4Mbps	10ms	5000byte
VoIP	32kbps	20ms	80byte

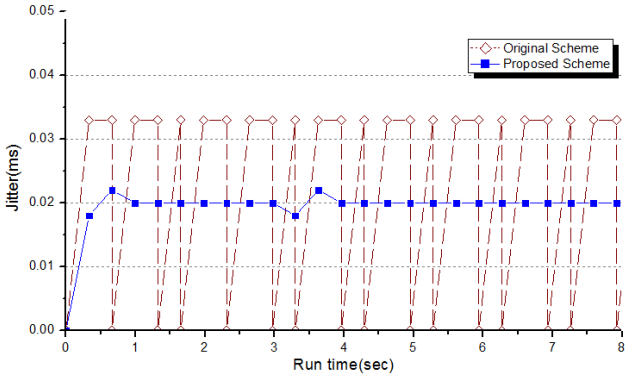


(A) Network topology for simulation

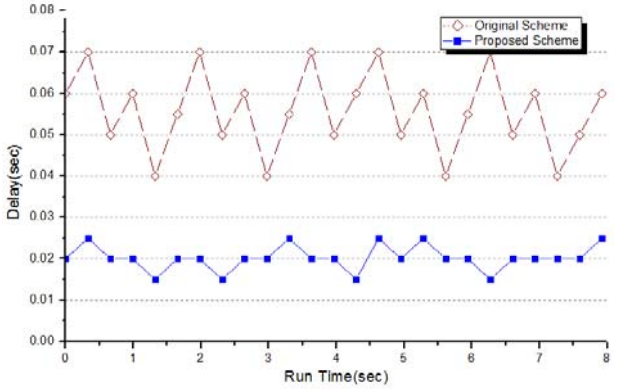


(B) Logical MAC Module

Figure 9. Simulator implementation



(A) Jitter of IEEE P1901 MAC and Proposed MAC



(B) Delay of IEEE P1901 MAC and Proposed MAC

Figure 10. Simulation result graph

Figure 10 shows simulation result. Figure 10(A) is a jitter graph. Packets were transmitted according to the AC cycle in the original scheme. But in the enhanced scheme, Packets were transmitted and received on time. This is due to the fact that RTS for first packet has TRINFO message that request timeslot for now and next packet. And the CSMA or Beacon region and reserved region can be interchanged between two cycles. Figure 10(B) shows delay of packets. Delay also has been improved. The reason is same that give higher priority to small and short interval packet.

V. CONCLUSION

Because of the increase of multimedia services in home which do not request extra line for communication, power line communication will be distributed and furthermore widely used. PLC being a wired communication environment, but has many of wireless characteristics. Due to other electronic devices, a lot of noise exists and unlike Ethernet, PLC MAC has a unique synchronization mechanism. The ongoing standardization and technology development will provide to PLC benefits that are for wired as well as for wireless communications. Those benefits being stability, safety and expansion of transmission distance which are not provided in the common wireless

As a result of our work, we could see that multimedia service can have enough performance. And we proposed a new scheme which reduces jitter and delay considered as original problems of IEEE P1901 MAC scheme when VoIP service is supported.

ACKNOWLEDGMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by MEST (No. 2009-0083838) Dr. CS Hong is the corresponding author.

REFERENCES

[1] IEEE., "Draft Standard for Broadband Over Power Line Networks: Medium Access Control and Physical Layer Specifications", IEEE P1901, December 2008 http://grouper.ieee.org/groups/1901/.

[2] Stefano Galli, Panasonic, Oleg Logvinov, Arkados. "Recent Developments in the Standardization of Power Line Comminications within the IEEE", IEEE Communications Magazine, pp. 64-71 July 2008

[3] Yu-Ju Lin, Haniph A. Latchman, and Richard E. Newman, University of Florida Srinivas Katar, Intellon Corporation. " A Comparative Performance Study of Wireless and Power Line Networks", IEEE Communications Magazine, pp. 54-63. April 2003

[4] Raphael Rom, Moshe Sidi, "Multiple Access Protocols Performance and analysis", Springer-Verlag, June 1989

[5] A. Varga, "The OMNeT++ Discrete Event Simulation System," Proc. of the European Simulation Multiconference, 2001.

[6] OMNeT++ 4.0 documentation, OMNET++ Commmunity www.omnetpp.org