전력선통신방식에서 센서데이터 전달을 위한 MAC 프로토콜 설계

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A Medium Access Control Protocol for Sensor Data in Powerline Communications

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요 약

홈네트워킹을 위한 데이터통신 기법으로 전력선통신 방식에 대한 수요가 증가되고 있다. 한편, 지능형 홈 서비스 중에서 집안의 현관, 창문, 가스밸브 등에 센서노드를 부착하여 침입이나 가스누출 시 댁내 사용자에게 비상상황을 알려주기 위한 홈 안전서비스의 활용이 가장 높을 것으로 예상되고 있다. 센서노드의 전원문제를 해결하기 위한 방안으로 전력선통신방식을 활용하는 것을 고려해볼 수 있는데, 일반적으로 센서정보는 음성이나 화상정보보다는 낮은 우선순위를 가진다. 이에 따라 댁내 안전에 문제가 발생하였을 경우 센서데이터가 즉각적으로 전달되지 못하는 경우가 발생할 수 있다. 이에 따라 본 논문에서는 긴급한 센서데이터를 전력선통신방식을 활용하여 즉각적으로 전송될 수 있는 HomePlug1.0 기반의 MAC 프로토콜을 제안하고 성능을 분석하였다.

ABSTRACT

With the ever increasing demand for data communication methods, powerline communication has become an interesting alternative method for data communication in home networking. For the purpose of home safety, several sensors will be installed at door, windows, gas alarm, etc. When considering home networking, the sensor data as well as other types of data should be supported in powerline communication. Usually the sensor data do not have priority over isochronous traffics (voice, video traffic), but in the case of urgent situation at home, the data of sensor being aware of the situation should be transmitted earlier than others. The objective in this paper is to develop a method for supporting an urgent data in home networking using powerline communication. We propose a modified algorithm of HomePlug 1.0 and show the results of computer simulation.

Keyword

MAC, PLC, Home Network, Sensor, Computer Simulation

Ⅰ. Introduction

The networks using electrical power distribution lines for data transmission are called Powerline Communications (PLC) networks, which nowadays become more and more attractive. Utility companies can use them not only as

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communication media for home networking, but also as "last mile" access services to all homes and offices, delivering internet access to every room where there is a power outlet. Compared with other alternative network, PLC networks have two appealing attributes, no need to use the expensive RF conversion hardware and power outlet everywhere in home or office.

The PLC networks were introduced to the U.S. consumer market in May 2002, and European PLC networks have also been deployed in recent years. With multiple outlets in almost every room, residential power lines are already the most pervasive network in the home or small office. The HomePlug 1.0 PLC standard, developed by the HomePlug Alliance [1], supports physical data rates of 14Mbps and is thus comparable to the 802.11b declared data rate.

Recently, the applications of PLC technology for home networking have been increasing due to the development of HomePlug Powerline Alliance. There is a home gateway for the home network and it can provide internet access and control the access of network when working under centralized mode. Other nodes of home network need either data (such as text data, sensor data) or multimedia traffic.

Especially the sensor data used for home security have different characteristics compared to ordinary text data. First, the rate of sensor node is much lower than other data node. Second, the several sensor nodes are installed at door, windows, and gas alarm and in ordinary case the priority of sensor data traffic is lower than voice or video traffics. But when an emergency situation is occurred, the priority of sensor data traffic should be highest than others. The objective in this paper is to develop a method for supporting an urgent data in home networking under powerline communication network.

The rest of the paper is organized as follows: Section 2 addresses the MAC (Media Access Control) protocol of HomePlug 1.0 for PLC. A suitable mechanism supporting urgent data is suggested in section 3 and shows the performance results. Section 4 presents the conclusions and future work.

Ⅱ. HomePlug1.0 Protocol

This section provides an overview of the HomePlug 1.0 protocol especially about the MAC layer [1, 2, 3].

2.1 MAC Protocol

The HomePlug 1.0 MAC layer uses channel access based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) to transport data from 46 to 1500 bytes long from encapsulated IEEE 802.3 frames as MAC Service Data Units (MSDUs). HomePlug 1.0 devices operate in an ad-hoc mode in the sense that devices communicate with each other freely, without any centralized coordination.

The frame structure of HomePlug 1.0 is depicted in figure 1.

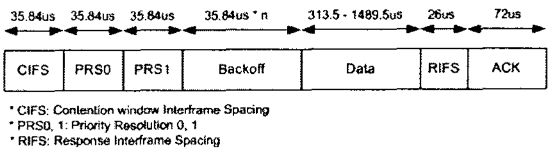

Figure.1 The HomePlug1.0 Frame Structure

The HomePlug 1.0 standard uses different terms and stages for interframe spacing and the contention windows than 802.11b. The RIFS shown in the figure is response interframe spacing. The spacing between the last frame and incoming frame is contention window interframe spacing (CIFS).

HomePlug 1.0 provides four priority classes, CA3 (Channel Access 3), CA2, CA1, and CA0, from highest to lowest. Priority resolution is done by asserting appropriate signals in the PRS0 and PRS1 slots. For example, to send a CA2 packet, the PLC device should assert a 1 in PRS0 and a 0 in PRS1, causing any node with CA1 traffic to defer. Nodes with CA3 data would assert a 1 in both priority slots. This effectively resolves contention between different priority classes. Contention within the same priority class is resolved during the backoff (contention) period.

The contention period is a form of CSMA/CA with a priority-dependent backoff window size schedule. For the two lower priority classes, the backoff schedule is 8-16-32-64 slots, while it is 8-16-16-32 slots for the two higher priority classes. On collision, the range of contention slots over which a transmission is started is increased according to the schedule. Aside from starting with a smaller range (8 slots compared to 32), a major difference from the IEEE 802.11 standard is that when a HomePlug node defers (detects another node's transmission in an earlier slot), it uses this information to backoff, but less aggressively than in the case of a collision. This technique serves to further reduce costly collisions.

2.2 Channel Access

When a station first starts contending for the channel, it randomly picks one of the first eight contention slots following the PRP (Priority Resolution Period) to start its transmission, setting a Backoff Counter (BC) to the number of slots to leave empty for others to use. Deferral Count (DC) keeps track of the number of times a station enters the Contention Window and has to defer to another station. As unused slots go by in contention periods at the same priority level as the traffic waiting to be sent by the station, the backoff counter is decremented until one of two things happens. If the BC reaches zero, the station starts transmission, then awaits a response if one is expected. If the DC reaches zero, then so many stations at the same priority level have made their presence known that the sender randomly picks a new value for the BC from the next larger range of values (again, depending on the priority level of its data), in much the same way that it would if it inferred a collision. This allows the extra information from deferrals to be used to avoid costly collisions. The figure 2 shows the channel access mechanism of HomePlug MAC protocol.

When a station sends a frame and either does not expect a response or receives a matching ACK from its destination, then the frame has successfully been sent and the next frame is readied for transmission. If it was the last segment in a service block, then success is reported to the host interface.

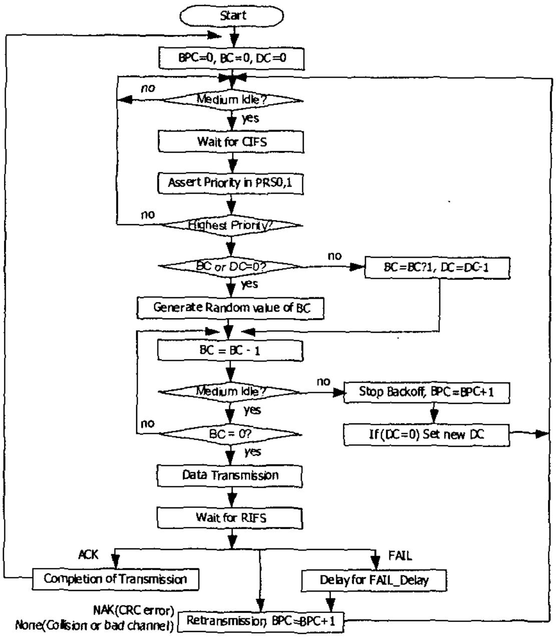

Figure 2. Channel Access Mechanism of HomePlug1.0

If a valid FAIL response is received, and the maximum number of FAIL retries (between 0 and 6) has not been exceeded, then the station waits an extended time (10 ms) before resuming its efforts. Otherwise, if it either receives a NACK or it infers that a collision has occurred, the station invokes the backoff procedure by increasing the contention window size in accordance with the backoff schedule, up to a maximum of 32 for CA3 and CA2, or 64 for CA1 and CA0), and picking a new delay time for the BC.

Table 1. Backoff Schedule

	CA3	CA2	CA1	CA0
	CW	DC	CW	DC
Initial	7	0	7	0
First BPC	15	1	15	1
Second BPC	15	3	31	3
Third and subsequent BPC	31	15	63	15

In Table 1, high priority is CA3 and CA2, low priority is CA1 and CA0. BPC is the Backoff Procedure Counter, which counts the number of times that the Backoff Procedure has been invoked due to collisions or deferrals. The BPC is reset to 0 after a FAIL, as the amount of traffic is expected to change after the long delay. DC is the Deferral Counter and CW is the Contention Window maximum (the minimum is zero, so the CW size is actually CW+1).

Collisions are inferred under several circumstances. First, if no response is detected when one is expected, then a collision is assumed, although this could be due to a bad channel.

Ⅲ. Proposed Method and Performance Results

In order to support the urgent sensor data in Powerline communication for the home networking, the HomePlug 1.0 MAC protocol should be modified suitable for the emergency situation. In this section, a proposed method is presented and shows the performance results.

3.1 Issues

A wide range of requirements will be brought to bear by customers in home networking technology. These include a no-new-wire installation and straightforward configuration and management. Unlike traditional requirements for networks that focus more on the data transmission, in home networking, the requirements of many types of service, such as data networking, VoIP (Voice over IP), Video/Audio streaming, network game, homeautomation, and home security, should be supported with equal importance.

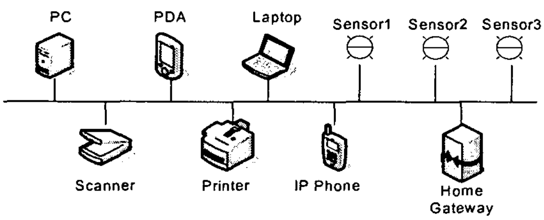

Figure 3. Topology of PLC Home Network

The network structure of PLC home networking is depicted in figure 3. There is a home gateway for the home network. It can provide internet access and control the access of network when working under centralized mode. Other nodes of home network need either data or multimedia traffic or sensor data traffic.

Especially the sensor data used for home security have different characteristics compared to ordinary data traffics. First, the rate of sensor node is much lower than other data node, usually below several tens of bps. Second, the several sensor nodes are installed at door, windows, and gas alarm and in ordinary case the priority of sensor data traffic is lower than voice or video traffics. But when an emergency situation is occurred, the priority of sensor data traffic should be highest than others.

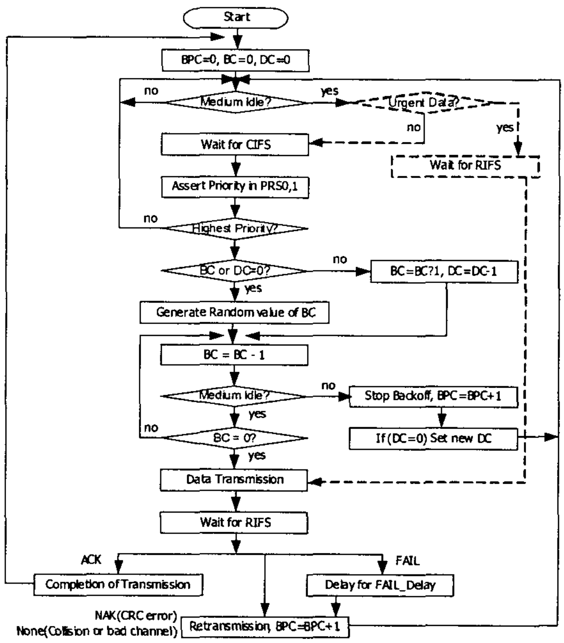

Figure 4. Proposed Algorithm

In order to support the wireless sensor node, the Zigbee Alliance [4] published a Zigbee specification that uses IEEE 802.15.4 for physical layer and lays network, application sublayer. In Zigbee, the power consumption is one of major problem to resolve but the power of commercial product of

Zigbee node does not keep work longer than a year. This problem makes annoy the dweller of home with changing the battery of sensor nodes. The Powerline communication would be a better solution for the battery problem of sensor nodes.

In order to support such sensor nodes in PLC, a method for supporting urgent data traffic in emergency situation is needed.

3.2 MAC Protocol modified for Urgent Data

The HomePlug 1.0 MAC protocol supports four priority classes. Usually the voice or video traffic has highest priority because they are sensitive to inter-arrival time of frames. In ordinary case, the sensor data have lower priority than the voice or video traffics, but in emergency situation the priority of sensor data should be higher than other traffics. The HomePlug 1.0 MAC protocol does not make an offer preemptable characteristic, so in this paper we suggest an algorithm to support the urgent sensor data immediately after an emergency situation occurred. The figure 4 shows a proposed algorithm.

As shown in figure 4, the proposed algorithm is straightforward and simple. Usually, when a medium is idle, the node waits for CIFS and participates in the PRP (Priority Resolution Period). If an urgent sensor data follows this procedure, the authority to access medium transfers to higher priority traffics. For example, when a sensor node detects an unauthorized person's irruption into the house through a window, the sensing data should be transferred to the home gateway and raises an alarm to notify an emergency situation. But at that time, if voice or video traffics flows the PLC network, then home gateway could not receive the sensing data because the sensor data have lower priority.

To resolve this problem, immediately after confirmation of medium-idle, the proposed algorithm checks whether urgent data are presented or not. If when an urgent data should be transferred, the node waits for RIFS and goes to the data-transmission step directly. Figure 4 shows the modified algorithm in dashed lines.

3.3 Performance Results

In order to evaluate the performance of proposed algorithm, the computer simulation is used. The simulation increases the number of voice node, sensor node, and data node one by one and investigates the delay time comparing to HomePlug 1.0.

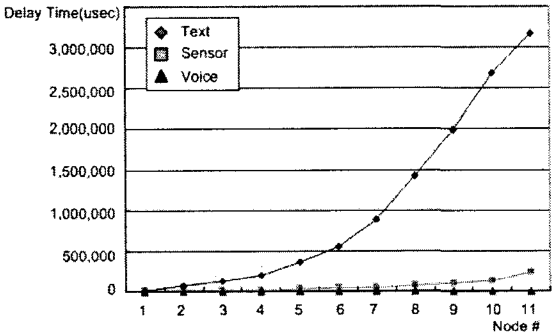

Figure 5. Simulation result: Delay time of Text(lowest priority), Sensor, Voice(highest priority) traffic using HomePlug1.0

First of all, the simulation is performed using the following parameters. There are three types of node generating text data, sensor data, and voice data. Ordinarily, the node generating text data has lowest priority, while the voice node has highest priority. The sensor node has middle priority. The arrival rate of text-data node follows exponential distribution with λ =9.97ms and average inter-arrival time of voice node and sensor node is 10ms and 1,000ms respectively. And offered load of text-data node is 0.9.

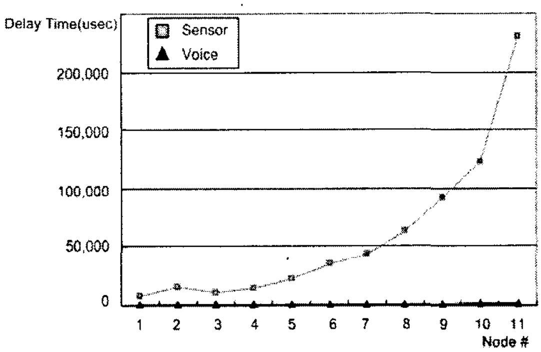

Figure 6. Simulation result: Detailed view of figure 5 for sensor and voice data.

The figure 5 shows the delay time of text-data, sensor, and voice node by incrementing the number of node in HomePlug 1.0. The delay time of sensor node and voice node seems to be suitably low value as expected. However, with detailed look of figure 5, the delay time of sensor node is rapidly increased by the number of node as shown in figure 6. When the number of sensor node is exceeded 9, the delay time becomes over 0.1sec, while the delay time of voice node is not more than 1,800usec even though the number of node is 11 as shown in figure 7.

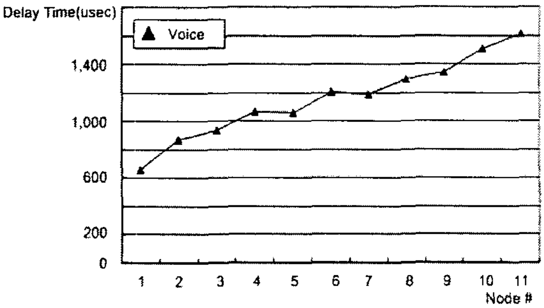

Figure 7. Simulation result: Detailed view of figure 6 for sensor data

In order to cope with emergency situation in the home, the delay time of sensor node should be réduced below the reasonable value. The simulation result of proposed method is depicted in figure 8. The delay time of sensor node keeps below 600usec as the incrementing number of node and the delay time voice node is almost similar with the value of figure 7.

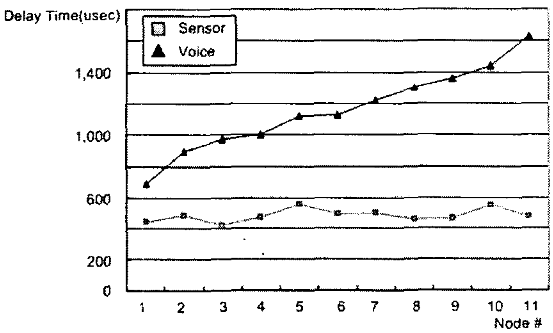

Figure 8. Simulation result: Delay time of sensor, voice traffic using proposed method

Ⅳ. Conclusions

We proposed a modified MAC protocol to support an urgent sensor data in Powerline communication network. In the HomPlug1.0, four priority classes are presented to support text, video, and voice data traffics, but when an emergency situation is occurred, the urgent sensor data cannot be delivered to home gateway or experiences excessive long delay because of lower priority. In order to overcome this problem, we suggested an algorithm based on the HomPlug1.0 MAC protocol. The computer simulation shows that the delay time of urgent sensor data is lower than that of voice data and tends regular values over the number of node. That the delay time of voice data does not become large in spite of modification of MAC protocol is noticeable.

Based on the proposed algorithm, future work will focus on the hardware implementation of sensor node and the evaluation performance in real PLC network environments.

Reference

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