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A Contention Based Medium Access Scheme for Energy Saving in WiMiedia Networks

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Abstract

The salient features of UWB networks such as high-rate communications, low interference with other radio systems, and low power consumption bring many benefits to users, thus enabling several new applications such as wireless universal serial bus (WUSB) for connecting personal computers (PCs) to their peripherals and the consumer-electronics (CE) in people's living rooms. As UWB devices are used widely, data traffic by UWB devices increases dramatically. However, when transmitting device and receiving device are communicate with each other, the remaining WiMedia devices maintains active mode for the time to complete the transmission MSDU, and there is a problem that unnecessary power consumption occurs. Therefore we propose new energy saving scheme to reduce unnecessary power consumption of WiMedia devices.

Keywords: *UWB, WiMedia, Energy Saving, HR-WPAN, Home Network*

1. Introduction

Recently, due to the integration of applications such as Wireless USB, Wireless Display, and Wireless Video / HDTV streaming, data transfer rates up to hundreds of Mbps is required. To meet these requirements, various wireless communication standards to support high data rate have been proposed and one of them is WiMedia standard [1-5].

WiMedia networks typically consist of a plurality of WiMedia devices. WiMedia devices have certain rules in order to receive or transmit data. In other words, when at least two WiMedia devices transmit data in the same time, the data conflict occurs. Thus, the WiMedia devices that want to receive data receive incorrect data. Therefore, WiMedia devices in WiMedia networks must transmit data not to overlap each other.

Figure 1 shows the example of WiMedia networks consisting of WiMedia devices A~E. WiMedia devices is located within a certain area of beacon period and each WiMedia device transmits beacon frame. In Figure 1, WiMedia device A transmits beacon frame to WiMedia devices B~E, and WiMedia device B transmits beacon frame to WiMedia devices A and C. WiMedia device C transmits beacon frame to WiMedia device A and B, and WiMedia device D transmits beacon frame to WiMedia device A and E. WiMedia device E transmits beacon

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frame to WiMedia device A and D. WiMedia device C transmits data frames to WiMedia device B within time slot reserved in beacon period. Also, WiMedia device E transmits data frames to WiMedia device D in reserved time slot.

Figure 2 shows the superframe structure used in WiMedia networks. As shown in Figure 2, the superframe in WiMedia network consists of beacon slot and 256 time slots. WiMedia devices in WiMedia networks require the sync information to synchronize the superframe.

Thus, WiMedia devices include the sync information in beacon frame and broadcast beacon frame to neighbor devices. In addition, WiMedia devices transmit data frames using reserved time slots.

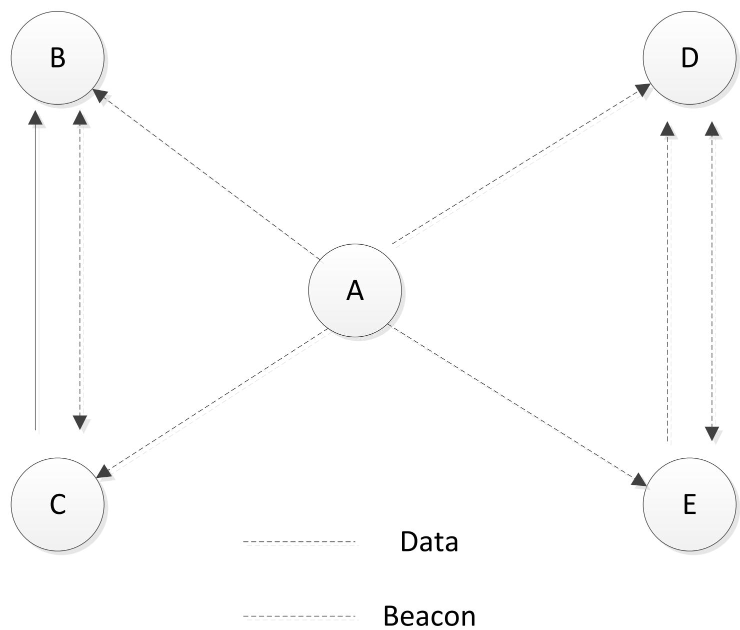

Figure 1. The example of WiMedia network topology

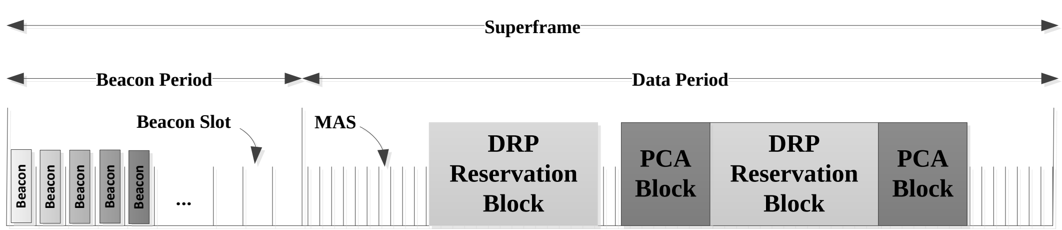

Figure 2. The example of WiMedia network topology

WiMedia devices typically find time slots that are not reserved by the adjacent WiMedia devices and inquire availability of time slots to receiving device. If the inquired time slots can be reserved, the receiving device notifies the acceptance of time slot reservation to transmitting device. If the inquired time slots cannot be used, the receiving device notifies the cancellation of time slot reservation to transmitting device. After a successful reservation of time slots, WiMedia devices communicate with each other in reserved time slots.

Figure 3 shows the active period and idle period of transmitting device C and receiving device B. In Figure 3, device A reserves MAS (Medium Access Slot) 0 and MAS 1 to transmit data frames to device B.

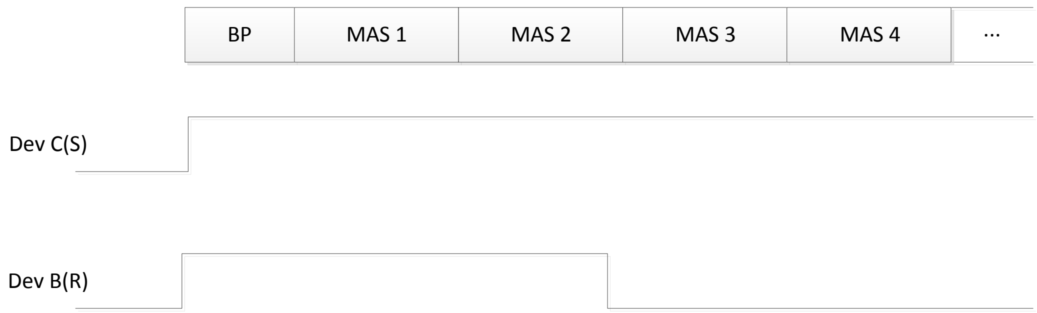

Figure 3. The example of power dissipation in WiMedia protocol

To transmit data frames to WiMedia device B, WiMedia device C maintains active state in reserved time slots, MAS 0 and MAS 1. Also, to receive data frames from device C, WiMedia device B maintains active state in reserved time slots, MAS 0 and MAS 1. However, WiMedia device C may be able to transfer all necessary data frames in MAS 0 and MAS 1. In addition, the situation that WiMedia device C does not transmit necessary data frames can occur by the deterioration of wireless channel between device C and device B or other conditions. Thus, WiMedia device C can maintain active state in MAS 2 and MAS 3 to check the availability of the adjacent time slot. If MAS 2 and MAS 3 do not use by other devices, device C can transmit data frames in MAS 2 and MAS 3. However, to save energy, device B maintains active state in MAS 0 and MAS 1 and switches idle state in MAS 2 and MAS 3. Therefore, if device C maintains active state in MAS 2 and MAS 3 regardless of the status of device B, it wastes the power. Also, when other devices use MAS 2 and MAS 3, device c wastes radio resource.

With the explosive growth of high-datarate applications in wireless networks, energy efficiency in wireless communications has recently drawn increasing attention from the research community. Several international research projects dedicated to energy-efficient wireless communications are being carried out [6-8]. However, recent studies on energy efficiency scheme mainly focused on the narrow band cases with centralized implementations. These proposed schemes, when applied for distributed implementations, are not straightforward.

Therefore, to solve this problem, we propose the contention based medium access scheme to save the energy in WiMedia networks.

2. Proposed Scheme

When WiMedia device detects data traffic received from other WiMedia device, it maintains active state in the proposed energy saving scheme. The detection of data traffic transmitted from other WiMedia device can be determined by the information of the received beacon frame. At this time, the information which WiMedia device receives and refers is TIM IE (Traffic Indication Map Information Element).

The TIM IE is used to indicate that an active mode device has data buffered for transmission via PCA. The TIM IE is illustrated in Figure 4.

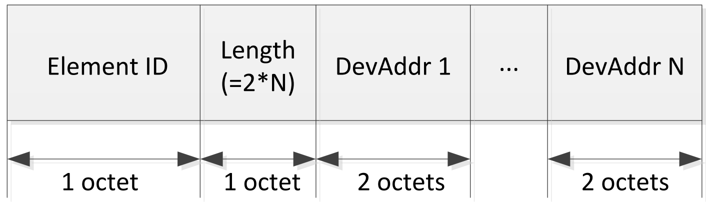

Figure 4. The format of TIM IE

Each DevAddr field is set to a valid target device address for which PCA traffic is buffered.

When WiMedia device does not detect data traffic transmitted from other devices, it maintains idle state. In other words, when the received beacon frame does not include the TIM IE or DevAddr field in TIM IE does not include device's address, WiMedia device operates on idle state.

On the other hand, when WiMedia device has data traffic to transmit to other devices, it maintains active state in PCA slot. In this way, the proposed scheme does not always maintain active state. If there is any other WiMedia device that transmits data frames, WiMedia device maintains active state in PCA slots. Otherwise it maintains idle state in PCA slot. Therefore, the proposed scheme can save the device's power

Figure 5 shows a part of superframe used in WiMedia networks that is composed in device A, device B, device C, and device D.

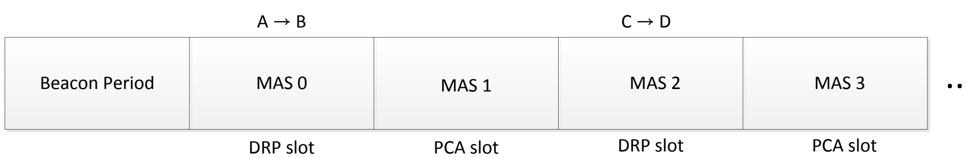

Figure 5. The method to transmit PCA traffic in the proposed energy saving scheme

As shown in Figure 5, MAS 0 is DRP slot to transmit data traffic from WiMedia device A to WiMedia device B, and MAS 2 is DRP slot to transmit data traffic from WiMedia device C to WiMedia device D. MAS 1 and MAS 3 are PCA slot. We assume that WiMedia device A uses the legacy WiMedia protocol, and the remaining devices use the proposed scheme. Also, we assume that WiMedia device B has data traffic to transmit to WiMedia device C. Thus, WiMedia device B broadcasts beacon frame including the TIM IE.

As shown in Table 1, device A, device B, device C, and device D maintain active state or idle state in each MAS.

WiMedia device A maintains active state in the reserved time slot, MAS 0. And WiMedia device A maintains active state to receive data traffic regardless of receiving TIM IE. In other words, device A maintains active state in MAS 1 and MAS 3 to receive data traffic. On the other hand, device A maintains idle state in MAS 2 that is not reserved for device A. Also, device B maintains active state in MAS 0 reserved for device B.

Because device B has data traffic to transmit to device C, it maintains active state in MAS 1 and MAS 3. On the other hand, WiMedia device B maintains idle state in MAS

2 that is not reserved for device B. And WiMedia device C maintains active state in MAS 2 reserved for device C.

Table 1. The state of each device in each MAS

	MAS0	MAS1	MAS2	MAS3
WiMedia device A (Legacy WiMedia)	Active	Active	Idle	Active
WiMedia device B (Proposed Scheme)	Active	Active	Idle	Active
WiMedia device C (Proposed Scheme)	Idle	Active	Active	Active
WiMedia device D (Proposed Scheme)	Idle	Idle	Active	Idle

Because WiMedia device C receives beacon frame including TIM IE that indicates data traffic to delivery from device B to device C, device C maintain active state in MAS 2. In other word, WiMedia device C maintains active state in MAS 1 and MAS 3 to receive data traffic. On the other hand, WiMedia device C maintains idle state in MAS 0 that is not reserved for device C.

WiMedia device D maintains active state in MAS 2 reserved for data reception of device D. Because WiMedia device D does not receive beacon frame including TIM IE that indicates data traffic to delivery from other devices to device D, device D maintain idle state in MAS 1 and MAS 3. In other words, WiMedia device D maintains idle state in MAS 1 and MAS 3 to prevent unnecessary energy waste. Also, WiMedia device D maintains idle state in MAS 0 that is not reserved for device D.

Because WiMedia device B and WiMedia device C maintain active state in MAS 1 and MAS 3, they can communicate with each other. Also, the proposed scheme can prevent unnecessary energy waste, since WiMedia device D maintains idle state in MAS 1 and MAS 3 that do not have data traffic to exchange with other devices.

3. Performance Evaluation

To evaluate the performance of proposed scheme, the simulation in the environment like Figure 5 is performed. As shown in Figure 5, four WiMedia devices are deployed, and have data traffic in the environment like Figure 5. The simulations are run for 1000 seconds and the common simulation parameters are summarized in Table 2.

Table 2. Simulation Parameters

Parameter	Value
Transmission Power	-41.3dB/Mhz
Bandwidth	528Mhz
Frame Size	512, 1024, 2049, 4096 Bytes
Symbol Length	312.5ns
Preamble Length	9.375us
Header Length	3.75us
SIFS	10us
MIFS	1.875us

Figure 6 shows the average delay performance comparison between proposed protocol and the legacy WiMedia standard. Delay for each packet consists of two parts, the queuing delay and the service delay. Service delay is defined as the time from when the packet becomes the head-of-line packet in the queue to the time the packet is received by the receiver. Here the packet length is equal to 2048 bytes and the data rate is equal to 48.8Mbps. The end-to end delay in proposed protocol is very similar with the delay in the legacy WiMedia standard. That is because both the proposed scheme and the legacy WiMedia standard use the same transmission scheme.

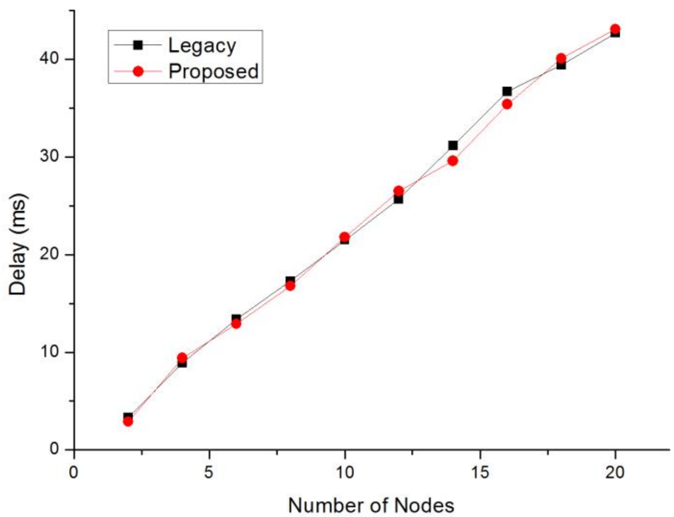

Figure 6. Number of WiMedia device vs. service delay

Figure 7 shows throughputs of a WiMedia device according to each UWB/PHY data rate. In Figure 7, the frame size transmitted by devices in a beacon group is fixed to 4095 bytes. These results show that the throughput of proposed scheme is very similar with the throughput of the legacy WiMedia standard. This is because both the proposed scheme and the legacy WiMedia standard use the same transmission scheme.

Figure 8 shows the dissipated power consumption of WiMedia devices. WiMedia device A uses the Legacy WiMedia standard, and device B, device C, and device D use the proposed scheme. As shown in Table 1, the number for the transition of idle state of device A~C is the same. Thus, the dissipated power consumption of device A~C is similar. However, the number for the transition of idle state of device D is smaller than other devices. Therefore the dissipated power consumption of device D is less than that of device that uses the legacy WiMedia protocol as seen in this figure. Because the proposed scheme switches the power mode to low power mode as soon as a WiMedia device does not detects the TIM IE included in beacon frame, it is possible to save the energy of device for the transmission of MSDU. Thus, the perfomance of the proposed scheme is more superior to that of the legacy WiMedia standard.

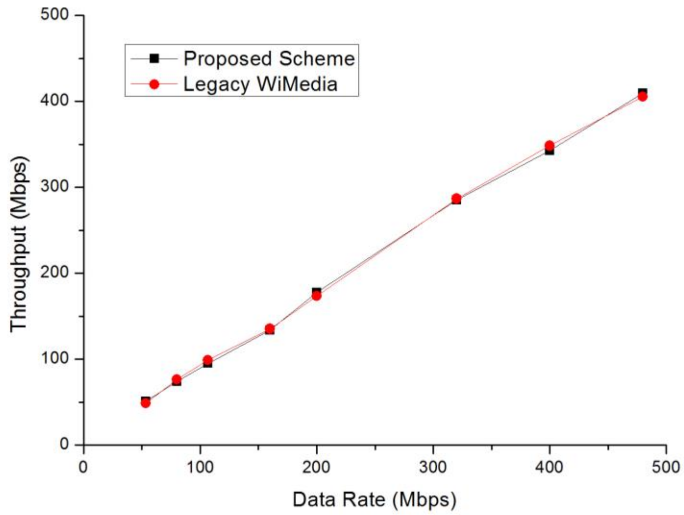

Figure 7. Throughput of a WiMedia device according to each UWB PHY data rate

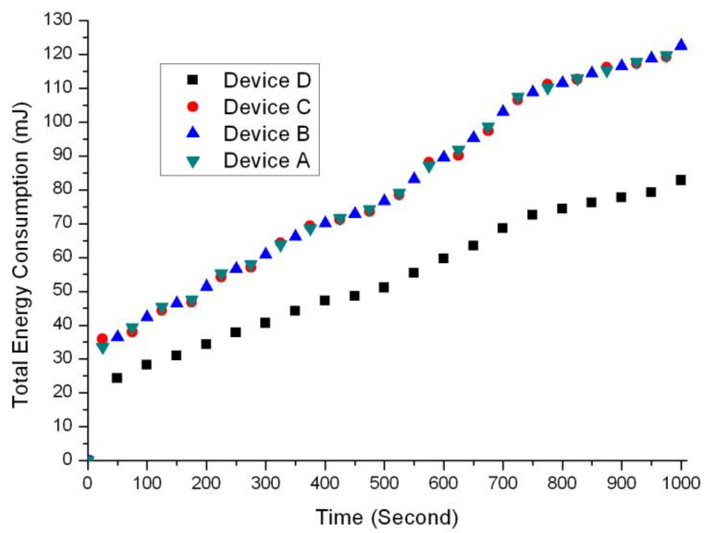

Figure 8. Energy consumption of device according to the operating time of WiMedia device

Figure 9 illustrates communication energy consumption of the whole network. It can be seen that the energy saving increases as the number of WiMedia device increases. This is because devices that do not exchange data frames maintain idle state and prevent unnecessary energy waste. In summary, the device-level energy-saving scheme is more energy efficient than the traditional one, and as the number of WiMedia devices increases, this effect will be more obvious.

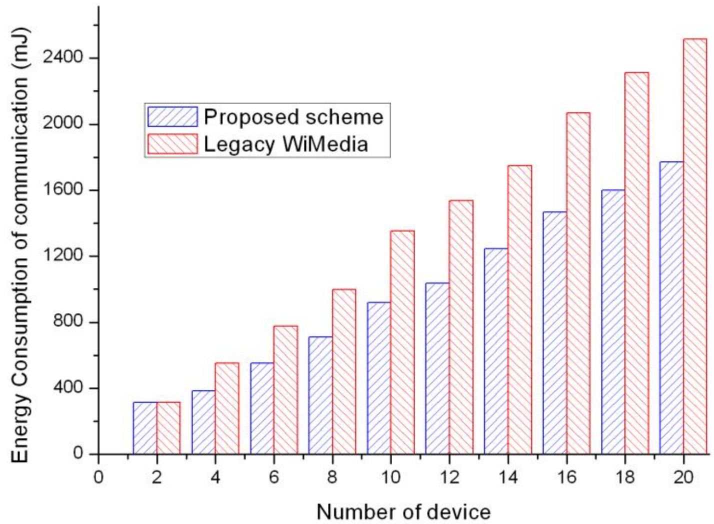

Figure 9. Communication energy consumption of the WiMedia network with different scales

4. Conclusion

In this paper, we propose noble energy saving scheme to reduce unnecessary power consumption of WiMedia devices. Because devices that do not exchange data frames maintain idle state, the proposed scheme can prevent unnecessary energy waste. Also, using the proposed scheme, the efficiency of energy saving increases as the number of WiMedia device increases. The simulation results show the performance of proposed scheme is more superior to that of the legacy WiMedia protocol. Also, the simulation results show that proposed scheme can use device's power efficiently.

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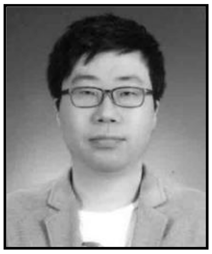

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