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An Energy Efficient Multimedia Streaming Scheme in WiMedia 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. Because the size of multimedia data frame, WiMedia device must transmit the fragment of MSDU. However, when the fragment of MSDU is lost, WiMedia device 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 power management scheme to reduce unnecessary power consumption of WiMedia devices in the case that the fragment is lost.

Keywords: *WPAN, UWB, WiMedia, Multimedia 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].

A device's power mode provided in WiMedia MAC specifications is hibernation mode with less power consumption and active mode with larger energy consumption than hibernate mode. In general, when Wimedia MAC device receives fragments of MSDU (MAC Service Data Unit), it operates in active mode. If WiMedia device in No ACK mode loses the fragment of MSDU transmitted from other WiMedia device, it does not receive all fragments belonging to the corresponding MSDU. However, even if WiMedia device does not receive fragments of the MSDU, it must be maintained its power mode to active mode since it cannot find the time to transmit MSDU and total number of fragments belonging to MSDU. In other words, when the fragment of MSDU is lost, WiMedia device maintains active mode for the time to complete the transmission MSDU. Thus, there is a problem that unnecessary power consumption occurs. In particular, because most multimedia service applications operate in the No ACK mode, the issue of power consumption due to the fragment loss further increases.

Therefore, new power management scheme is needed so that the sending WiMedia device transmits the time it takes to transfer MSDU, and the receiving WiMedia device can control its power mode in the case of the fragment loss.

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

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wireless communications are being carried out [6-10]. 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, in this paper, we propose new power management scheme to reduce unnecessary power consumption of WiMedia devices in the case that the fragment is lost.

2. Background

2.1. Fragmentation and reassembly Scheme in WiMedia specification

A source device can fragment each MSDU/MCDU. A device does not fragment any MSDU/MCDU to more than mMaxFragmentCount fragments. Fragments can be of varying sizes. Once a device transmits a frame containing a whole MSDU/MCDU or a fragment thereof, the device does not fragment or re-fragment the frame, unless the device receives a B-ACK or N-ACK response that indicates that the whole MSDU, or all its fragments were not received. The device does not create frame fragments smaller than mMinFragmentSize.

The device sets the Fragment Number field in the first fragment to zero. It sets each subsequent fragment to the Fragment Number field in the previous fragment plus one. The device does not increment the Fragment Number field when a fragment is retransmitted.

A device assigns the same Sequence Number to all fragments of an MSDU/MCDU. The device completely reassembles an MSDU/MCDU in the correct order before delivery to the MAC client. The device discards any MSDU/MCDU with missing fragments. If the No-ACK policy is used, the recipient device shall discard an MSDU/MCDU immediately if a fragment is completely received within an implementation-dependent timeout.

If B-ACK is used, unacknowledged fragments from multiple MSDUs belonging to the same stream can be retransmitted in the same sequence. In this case it is the responsibility of the recipient device to deliver the MSDUs in the correct order to the MAC client.

If a source device discards a fragment of an MSDU/MCDU, the device discards all fragments of the MSDU/MCDU.

2.2. Power Management Scheme in WiMedia specification

A device can be in one of two power management modes in each superframe:

- Active mode: the device sends and receives beacons in the current superframe.
- Hibernation mode: the device does not send a beacon or other frames in the current superframe.

Before entering hibernation mode, a device announces in previous superframes that it is entering hibernation mode.

A device using hibernation mode operates according to the following rules:

- A device signals its intent to go into hibernation mode by including a Hibernation Mode IE in its beacon. The Hibernation Duration field in the Hibernation Mode IE shall contain a non-zero value that specifies the duration of the hibernation period.

A device may signal its intent to go into hibernation mode in several superframes. The value of the Hibernation Countdown field in the Hibernation Mode IE is set to indicate the number of remaining superframes before the device enters hibernation mode. In each successive superframe, the device reduces the value of the Hibernation Countdown field by one. If this field is set to zero, the device enters hibernation mode at the start of the next superframe.

- When in hibernation mode, the device does not send a beacon or other traffic. The device must terminate all established DRP reservations before entering hibernation.
- A device can leave hibernation mode prior to the end of its announced hibernation period by sending its beacon.
- A device in hibernation mode scans for beacons during the BP for one or more superframes immediately prior to the end of its hibernation period, in order to re-establish synchronization.
- If a device exiting hibernation mode finds that its former beacon slot is neither occupied nor encoded as occupied with a DevAddr not its own in the BPOIE of any beacon received by the device in the last superframe, the device may transmit a beacon in that beacon slot. Otherwise, the device transmits a beacon as if it were doing so for the first time.

Active mode devices in the presence of hibernation mode devices shall operate as follows:

- If an active mode device receives a neighbor's beacon that includes a Hibernation Mode IE, the device considers all DRP reservations with that neighbor to be terminated at the start of its hibernation period. An active mode device does not commence any communication with a hibernation mode device until that device leaves hibernation mode. After receiving a beacon that includes a Hibernation Mode IE with Hibernation Countdown less than or equal to mMaxLostBeacons, an active mode device that misses the remaining expected beacons shall consider the device to be in hibernation mode as indicated in the Hibernation Mode IE.
- If a device does not receive a beacon from a neighbor at the end of the hibernation duration indicated in the neighbor's Hibernation Mode IE, it treats the neighbor's beacon slot as occupied, but does not indicate it as occupied in its BPOIE, for up to mMaxHibernationProtection after the neighbor entered hibernation or until any beacon is received in the neighbor's beacon slot.

3. Proposed Scheme

In this paper, we propose the Power Management scheme for energy-efficient multimedia streaming in WiMedia networks. When a device receives the fragment of multimedia data, the proposed scheme checks whether the fragment of multimedia data is lost or not. If the fragment is lost, a device checks the duration field of previously received fragment and save its energy by switching into sleep mode for interval set to duration field.

The fragment loss is determined by comparing the sequence number of received fragment and the sequence number of expected fragment. If the sequence number of received fragment is larger than the sequence number of expected fragment, the device determines for the fragment of multimedia data to be lost.

In this case, the time set in the duration field is the time from the received fragment MSDU to the last fragment of the time.

Figure 1 shows the multimedia streaming service performed in WiMedia network.

Figure 1. The example of the multimedia streaming service in WiMedia networks

In Figure 1, WiMedia devices use the No ACK(Acknowledgement) policy. The transmitting device divides multimedia data frame into multiple fragments and transmits fragments to receiving WiMedia device.

In this case, the sending device contains the sequence number of fragment in Wimedia MAC MAC header and transmits fragments of multimedia data frames to the receiving side. Figure 2 shows the format of proposed MAC frame header.

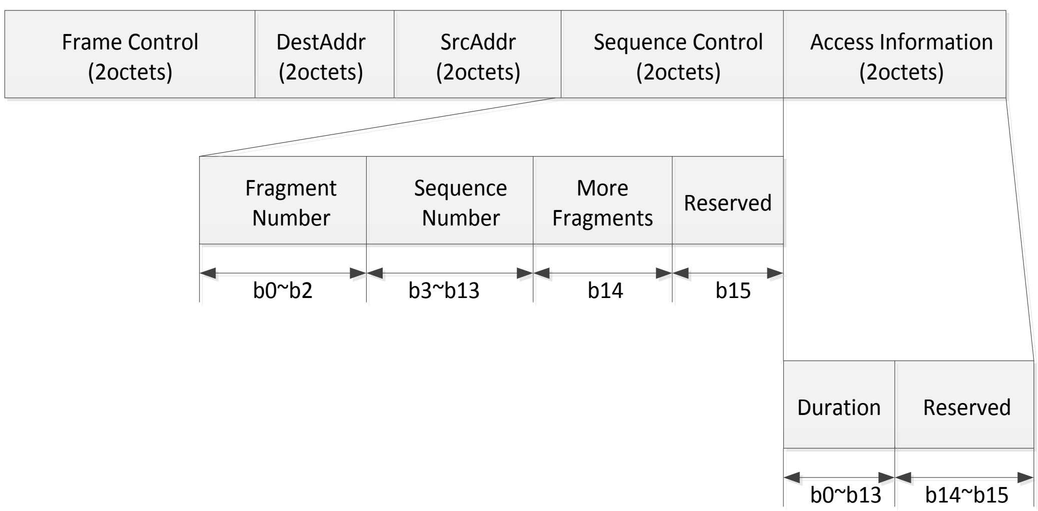

Figure 2. The format of proposed MAC frame header

In Figure 2, the sequence number includes the MSDU(MAC Service Data Unit) ID and fragment number, and the MSDU ID is a component to identify MSDU and the fragment number is component to verify the sequence of the fragment that divides MSDU.

Also, the MSDU fragment includes the duration field set to the time from the fragment of the sending MSDU to MSDU fragment with the last fragment number.

The receiving device determines whether the MSDU fragment is lost based on the sequence number of the received fragment and the expected fragment.

If the fragment number of received MSDU fragment is larger than the fragment number of expected fragment, WiMedia device determines that MSDU fragment is lost.

When MSDU fragment is lost, the WiMedia device checks the duration field in the received MSDU fragment, it enters into sleep mode or idle mode for the time set to the duration field.

When the set time has elapsed after receiving MSDU fragment, WiMedia device switches the power mode from low power mode to active mode.

In other words, WiMedia device can reduce unnecessary power consumption by switching the power mode from active to low power mode for time transmitting the lost fragment.

Figure 3 shows the process of proposed scheme.

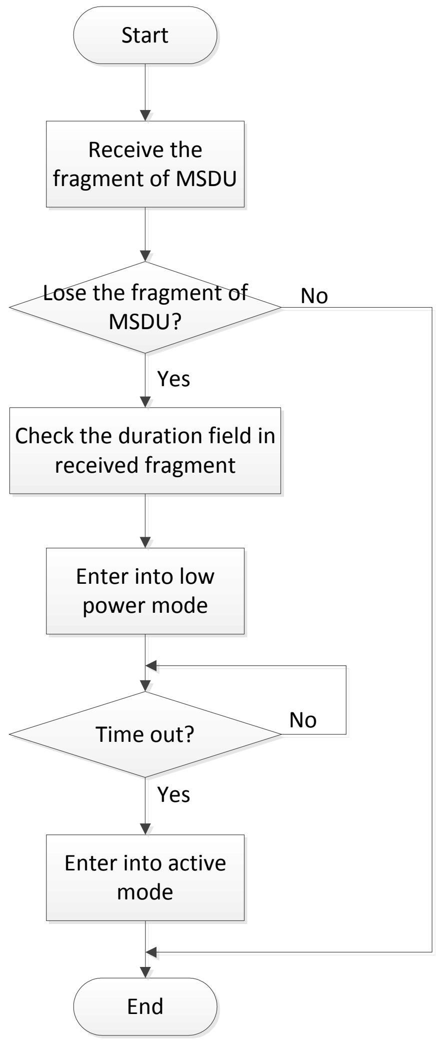

Figure 3. The process of proposed scheme

As shown in Figure 3, the WiMedia device receives MSDU fragment transmitted by multimedia streaming service provider. The WiMedia device that receives MSDU fragment determines whether MSDU fragment is lost or not. In other words, it determines whether another MSDU fragment transmitted by multimedia streaming service provider exists between the previously received fragment and the currently received fragment.

In this case, WiMedia device can determine the loss of fragment based on the sequence number of received fragment and expected fragment.

WiMedia device compares MSDU ID of the received fragment with MSDU ID of the expected fragment, and if two MSDU IDs is the same, it determines the loss of fragment based on the fragment number of the received fragment and the expected fragment. As a result, if MSDU fragment is lost, WiMedia device checks the duration field in the received fragment. In this case, the duration field is set to the time from the received MSDU fragment and the last MSDU fragment with the same MSDU ID.

When the duration field is verified, the Wimedia device enter into low power mode during a time set in duration field.

After this, the Wimedia device checks whether a time set in duration field is over. If a set time is over, it switches its power mode back to active mode. In other words, Wimedia device reduces power consumption by switching to low power mode for transmission time with lost fragment. And when the fragment transmission time with the lost fragment is over, the WiMedia device enters the power mode into active mode for receiving the next MSDU.

Figure 4 shows the process for the estimation of the fragment loss shown in Figure 3.

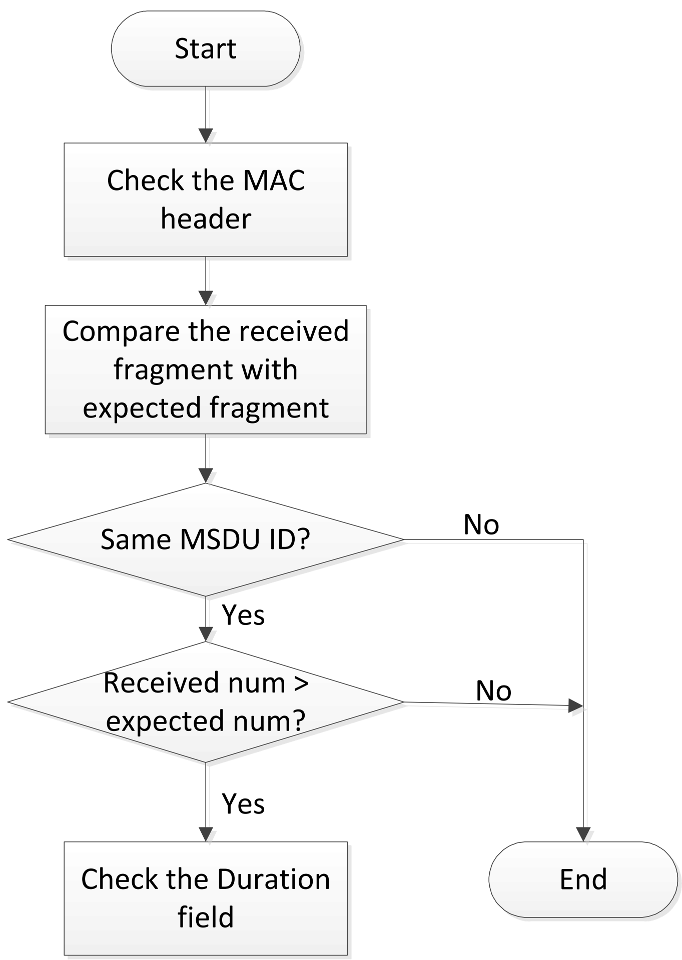

Figure 4. The process for the estimation of the fragment loss shown in figure 3

In Figure 4, to determine the loss of MSDU fragment, the WiMedia device checks the MAC header of received fragment. After this, it compares the sequence number included in the MAC header of received fragment with the sequence number of the expected fragment. In this case, it determines whether two MSDU IDs are the same by comparing the MSDU ID of the received fragment and the expected fragment. If the MSDU ID of the received fragment and the MSDU ID of the expected fragment are the same, the WiMedia device determines whether the sequence number of the received fragment is larger than the sequence number of the expected fragment. If the sequence number of the received fragment is larger than the sequence number of the expected fragment, the WiMedia device determines that the MSDU fragment is lost.

Figure 5 shows the example of the proposed scheme.

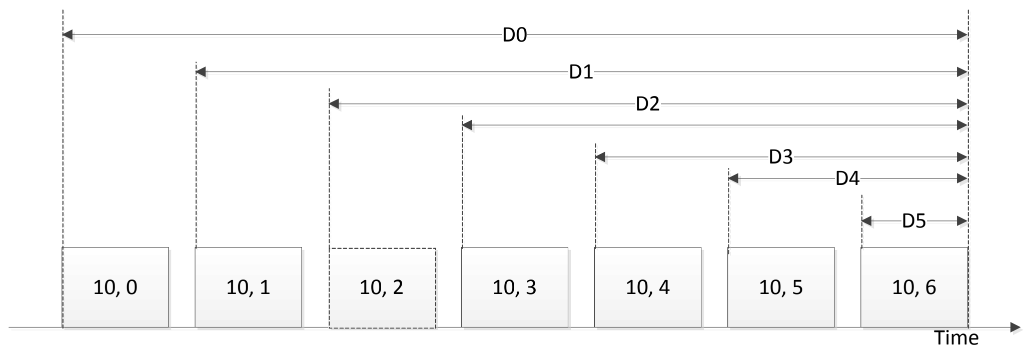

Figure 5. The example of the proposed scheme

As shown in Figure 5, the MSDU ID of MSDU is 10, and MSDU is divided into 7 fragments with 0-6 fragment number.

In Figure 5, the proposed fragment ID is composed of (MSDU separator, fragment number). Because the fragment ID (10, 1), *i.e.*, the fragment number of MSDU fragment transmitted by multimedia streaming service provider is equal to the fragment number of the expected fragment number, the WiMedia device determines that the fragment is not lost.

The other hand, if the fragment is lost with the fragment ID that is (10, 2), the WiMedia device receives the fragment with the fragment ID that is (10, 3). In this case, because WiMedia device receives from the fragment with (10, 1) of fragment ID, the fragment ID of the expected fragment is (10, 2).

The WiMedia device checks the MAC header of the received fragment and it checks the sequence number of the received MAC header. It determines whether the fragment is lost based on the fragment ID (10, 2) of the expected fragment and the fragment ID (10, 3) of the received fragment. Because the fragment number 3 of the received fragment is larger than the fragment number 2 of the expected fragment, the WiMedia device determines that the fragment with MSDU ID 10 is lost.

After this, because Wimedia MAC device lost the fragment, it extracts the duration filed from the received fragment, and it checks the time information (D3) set in duration field.

WiMedia device can reduce unnecessary power consumption by switching power mode to low power mode during D3.

When D3 is over, WiMedia device switches the power mode back to active mode to receive the next MSDU.

4. Performance Evaluation

In this section, we analyze and evaluate the performance of the proposed resource allocation method.

The simulations are run for 1000 seconds and the common simulation parameters are summarized in Table 1. We consider a multimedia application with a wireless IPTV and a personal video recorder (PVR) recording the same program. At some point, the user picks up a remote control and tunes the set-top box (STB) to start the IPTV program. The PVR in the STB simultaneously starts to record the same program to a wirelessly connected external hard disk drive that is located in a closet next to the living room. Assume the video source of the service provider generates an MPEG-4 stream using Real-Time Transport Protocol (RTP) [11] as transport, and table 7 shows the token bucket TSPEC(Traffic Specification) of the stream [13].

Table 1. Simulation parameters

Parmeter	Value
Transmission Power	-41.3dB/Mhz
Bandwidth	528Mhz
Symbol Length	312.5ns
Preamble Length	9.375us
Header Length	3.75us
SIFS	10us
MISF	1.875us

Table 2. A Token bucket TSPEC of traffic streams

Mean Data Rate	4.13 Mbps
Peak Data Rate	14.8 Mbps
Maximum Burst Size	131350 bytes
Maximum Packet Size	1490bytes
Maximum allowable delay	64ms

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 discard MSDU that has the fragment loss and use the same transmission scheme.

As shown in Figure 6, the delay of the proposed scheme does not exceed the maximum allowable delay for IPTV application defined in TSPEC.

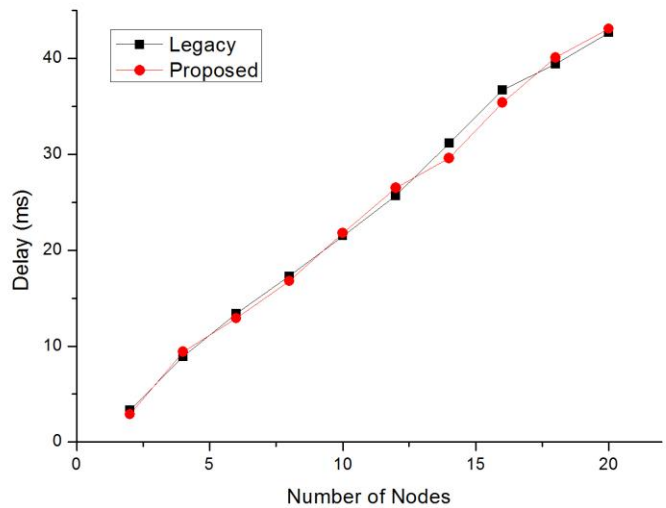

Figure 6. Number of WiMedia device vs. service delay

Figure 7 shows throughputs of a WiMedia D-MAC 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 discard MSDU that has the fragment loss and use the same transmission scheme.

Figure 8 shows the dissipated power consumption of WiMedia device that receives multimedia data from multimedia server. The dissipated power consumption of device that uses proposed scheme is less than that of device that uses WUSB protocol as seen in this figure. Because the proposed scheme switches the power mode to low power mode as soon as a WiMedia device detects the fragment of MSDU loss, it is possible to save the energy of device for the transmission of MSDU that the fragment is lost. Thus, the perfomance of the proposed scheme is more superior to that of the legacy WiMedia.

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. 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.

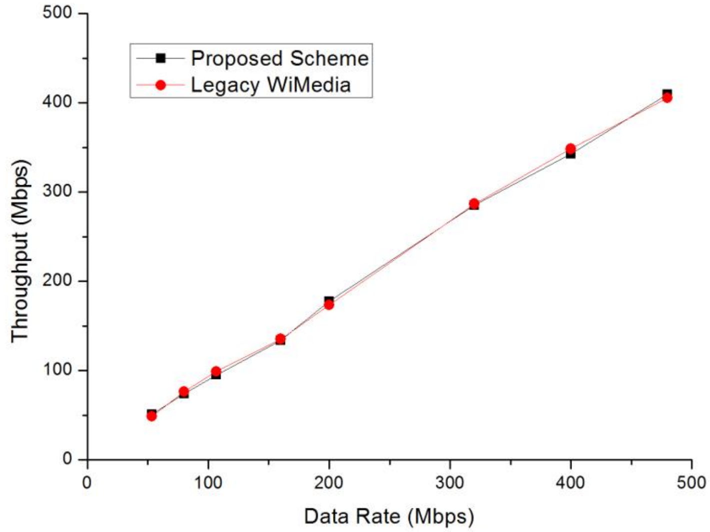

Figure 7. Throughput of a WiMedia device according to each UWB PHY data rate

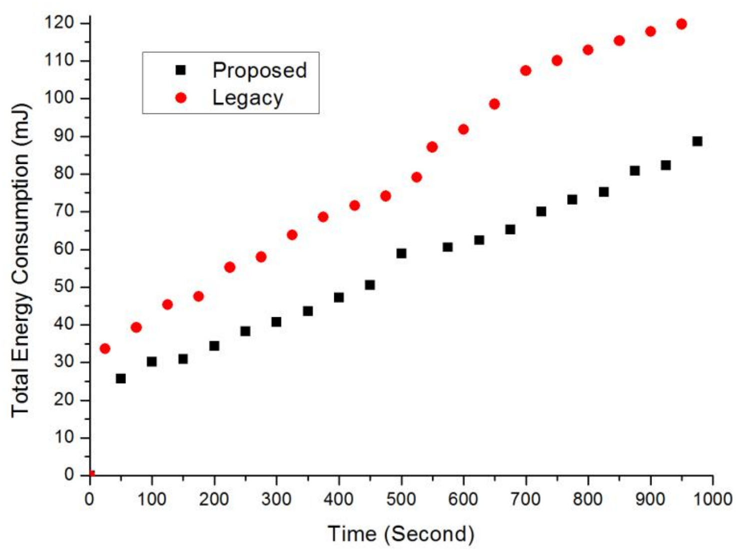

Figure 8. Energy consumption of device according to the operating time of WiMedia device

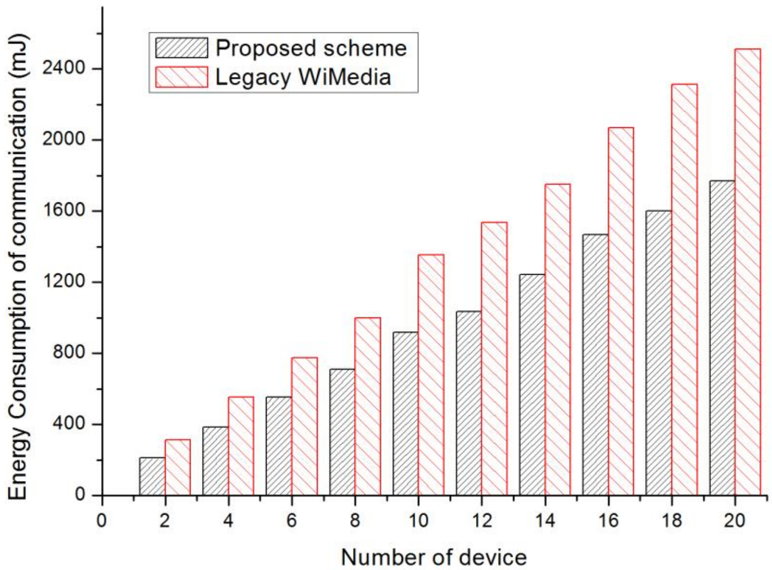

Figure 9. Communication energy consumption of the WiMedia network with different scales

5. Conclusion

In this paper, we propose noble power management scheme to reduce unnecessary power consumption of WiMedia devices in the case that the fragment is lost. When the fragment is lost, the proposed scheme can reduce unnecessary power consumption by switching the power mode to low power mode. Also, using the proposed scheme, buffering of multimedia data is easy since it is possible to predict the receipt time of the following fragment. 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 be applied to multimedia application like IPTV and DVD player.

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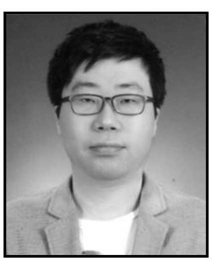

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