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Multi-helper Relay Based WUSB/DRD/WLP Protocol in WiMedia Distributed MAC Systems

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Abstract

In this paper, we propose a cooperative protocol of relay-based WUSB/DRD and WLP device in the WSS of WiMedia environment. For this, we investigate a RNT table configuration and algorithm of RNS relay node to be used in relay-based cooperative communication. Then, we describe the feature of the device to configure the WLP network and propose a cooperative protocol for WUSB/DRD/WLP device communication. The proposed cooperative protocol can communicate with WUSB/DRD/WLP devices by using the standard DRP reservation and WUSB DRP reservation.

Keywords: *WiMedia, WUSB (Wireless USB), WLP (WiMedia logical link control protocol), relay-based cooperative communication*

1. Introduction

In recent years, the demand for multimedia services of high quality in a wireless home network environment is growing gradually. WiMedia Alliance [1], more than 170 companies gathered, announced the standard of WiMedia D-MAC (Distributed-MAC) to allow a physical layer based on UWB (Ultra Wide Band) and a variety of applications such as wireless USB, wireless 1394, wireless IP, and Bluetooth. WiMedia D-MAC support the distributed media access method [2].

Relay transmission can improve the throughput and reduce energy consumption in the multi-rate wireless network. This is because it can be reduced the transmission time to execute relay transmission via high speed link compared with the case of transmitting directly through slow links. In order to enable the relay transmission, relay-based MAC protocols have been proposed. CoopMAC [3] is a relay-based cooperative MAC protocol in IEEE802.11. Helper (or Relay) is to support relay transmission in the course of the RTS/CTS exchange here. However, CoopMAC causes control overhead because of exchanging the RTS/CTS. Therefore, it does not fit in a multi-media applications that are sensitive to delay. IEEE802.15.3 [4] proposed centralized MAC protocol for UWB PAN to support relay transmission. Relay-based MAC protocol show enhanced performance in terms of throughput

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and energy efficiency but centralized MAC protocol has the disadvantage in terms of flexibility and scalability [5].

Wireless USB (WUSB) technology combined a wired USB technology and wireless technology based UWB by universal use of wired USB technology. Wireless USB technology adds the convenience of wireless to the performance of wired USB and security features. And the relationship between the host and the device of Wireless USB is a star topology which is connected directly as the point-to-point. Wireless USB utilize WiMedia UWB as a wireless transmission medium. And the UWB transmission technology, as a technology for ultra high-speed short-range wireless network, can communicate with neighboring device in the 10m range at speeds of up to 480Mbps [6]. It is used not only in the home network but also in various applications because of features that have low power consumption, difficult wiretapping, excellent security, and accurate position recognition.

UWB WiMedia devices can coexist with the wireless USB network in the same radio environment depending on the application. And communication between these networks is required in some cases. For this reason, WiMedia alliance defined a standard of WLP (WiMedia logical link control protocol) that specifies the requirements and frame format for transferring packets of network layer to the WiMedia radio platform [7]. This standard was defined the plan for support to connect the frames between WLP protocol and Ethernet protocol or other similar network protocol as well as security between devices.

All WLP devices belong to one or more WLP service sets (WSSs) [8]. Before two devices can exchange data frames, the devices must discover each other, enroll in and activate a common WSS, and establish a connection using the WSS properties. A device may create a new WSS or enroll in an existing WSS at any time. Once a device has created or enrolled in a WSS, it may activate the WSS to communicate with other devices enrolled in the WSS. A device with an activated WSS can connect to any neighbor that has also activated the WSS.

Client devices may communicate directly with other client devices that belong to the same WSS. They may also communicate with other client devices and nodes, such as Ethernet stations, by using the services of client bridges.

Client bridges forward frames to or from client devices that have requested bridge services. Client devices are the original source or ultimate destination of data traffic conveyed in WLP frames. Client devices direct frames to a client bridge in order to communicate with destination nodes reachable through the client bridge. A client bridge and client device must belong to the same WSS for the client bridge to provide bridge services.

In this paper, we propose a cooperative protocol of relay-based WUSB/DRD [9] and WLP device in the WSS of WiMedia environment. For this, we investigate a RNT table configuration and algorithm of RNS relay node to be used in relay-based cooperative communication. Then, we describe the feature of the device to configure the WLP network and propose a cooperative protocol for WUSB/DRD/WLP device communication.

2. RNT Table Configuration and RNS Relay Node Decision Algorithm

A relay-based cooperation communication as shown in Figure 1, when the state of the channel between the source node(S node) and the target node (T node) is not good, is a method that is advantageous in terms of power consumption and the time to send and receive data through relatively good relay nodes(R node). Recently, due to efficient communications of device that exists implementation restriction in terms of cost and power consumption, multi-hop relay cooperative communication methods have been proposed. CoopMAC method is proposed and proved a performance improvement through efficient relay communication in wireless LAN (WLAN) system. However, CoopMAC causes control overhead because of exchanging the RTS/CTS. Therefore, it does not fit in a multi-media applications that are sensitive to delay.

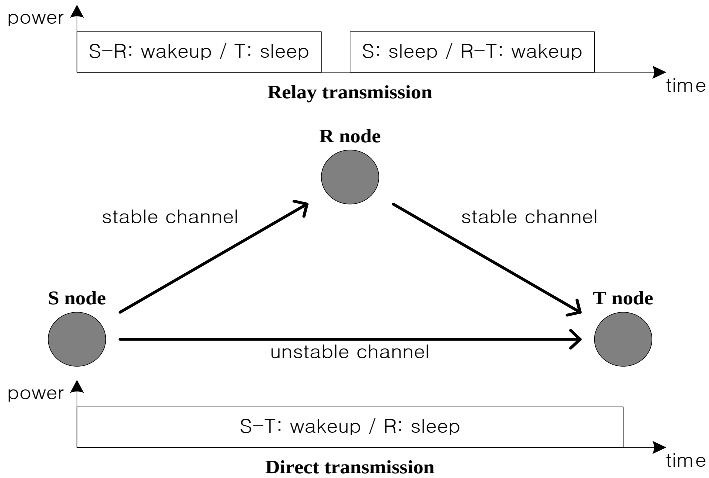

Figure 1. A relay-based cooperative communication

Link Feedback Information Element (IE) is defined in the WiMedia MAC protocol. There are ideal PHY data rate and information of the transmission power in Link Feedback IE, and it is transferred to the transmit device from the receiving device. As a result, all link feedback information on any device may be transmitted riding on the Link Feedback IE one. The format of the Link Feedback IE and the Link field are shown in Figure 2, Figure 3, and Figure 4. DevAddr field of the Link field format indicates the device address of the source transmission device that provides feedback.

octets: 1	1	3		3
Element ID	Length (=3xN)	Link 1	…	Link N

Figure 2. Link Feedback IE format

bits: b23-b20	b19-b16	b15-b0
Data Rate	Transmit Power Level Change	DevAddr

Figure 3. Link field format in Link Feedback IE

Value	PHY Data Rate	Value	PHY Data Rate
0	53.5 Mbps(=$R_{PHY-MIN}$)	5	320 Mbps
1	80 Mbps	6	400 Mbps
2	106.7 Mbps	7	480 Mbps
3	160 Mbps	8-15	Reserved
4	200 Mbps		

Figure 4. Data Rate field format

It can choose a transport transmission path to support a minimum delay and maximum data rate by using the link feedback information of the WiMedia devices. Therefore, by sending the new Reason code of the DRP Control field added to the DRP protocol provided by the WiMedia MAC standard, All WiMedia MAC devices can select the transfer path that supports higher data rates. Distributed cooperative D-MAC technology use a new RNT (Relay Node Table) and a Reason code. And, it needs the process of negotiating a new cooperative relay DRP.

In order to select a potential relay device required for data relay transmission, all devices belonging to the WiMedia beacon group must be set and maintained the RNT. Formation and update of RNT is done by receiving the Link Feedback IE which is put within the beacon neighbor device sent every superframe. Data transfer rate of information that can be best received normally a data frame that was sent by the sender is included in the Link Feedback IE.

Data rate information of the neighboring devices that is included in the received Link Feedback IE is stored in the RNT. As shown in Table 1, RNT is composed of Source-DEVAddr, PHY Data rate, and the Dest-DEVAddr. DEVAddr field indicates the address of neighboring devices and PHY Data rate field shows the optimal PHY data rate of between Source-DEVAddr and Dest-DEVAddr. Dest-DEVAddr field indicates the address of one-hop destination device transferred by the Source-DEVAddr directly. The device which reserves MAS (Medium Access Slot) [2] for data transfer checks the RNT.

Table 1. Configuration of RNS table

Source-DEV Addr	PHY Data Rate	Dest-DEV Addr

After getting information about the device in the neighborhood, it is necessary to determine the optimum device for providing the smallest relay transmission time from RNT table information. For this reason, it is necessary to calculate the transmission delay time in the available paths (direct path and relay path). Table 2 describes expression used to calculate the transmission delay time of each path. For Direct transmission, PHY data rate between the source and target devices should be used. On the other hand, relay transmission time is the sum of TS-R and TR-T. If relay transmission time is shorter than the direct transmission time, source device performs the relay transmission by determining relay transmission is suitable from the point of view of maximizing the throughput. When rearranging equation (1) so as to satisfy the condition of Trelay < Tdirect, in the formula (2), RNS to select a relay node (Relay Node Selection) criteria are derived.

$$T_{direct} = T_{S\text{-}T}\ ,\qquad T_{relay} = T_{S\text{-}R} + T_{R\text{-}T}\ ,\qquad T_{relay} < T_{direct} \tag{1}$$

Relay Node Selection(RNS) Criterion

$$R_{S\text{-}T} \cdot R_{R\text{-}T} + R_{S\text{-}R} \cdot R_{S\text{-}T} < R_{S\text{-}R} \cdot R_{R\text{-}T} \tag{2}$$

Table 2. Configuration of RNS formula

Parameter	Meaning
T_{direct}	Direct transmission time from the source node to the target node
T_{relay}	Relay transmission time from the source node to the target node
$T_{S\text{-}R}$	Transmission time from the source node to the relay node
$T_{R\text{-}T}$	Transmission time from the relay node to the target node
$R_{S\text{-}R}$	Data rate from the source node to the relay node
$R_{R\text{-}T}$	Data rate from the relay node to the target node
$R_{S\text{-}T}$	Data rate from the source node to the target node

Relay-based DRP conforms to WiMedia D-MAC protocol to be compatible with the existing WiMedia D-MAC. Relay DRP supports the relay cooperative communication in WiMedia D-MAC protocol by using the three reserved Reason code (reservation details of status code). Reason code used in additional is shown in Table 3. Reason code of ‘Relay Req’ send from the source node to the relay node for request of DRP reservation. And reason code of ‘Realy Ntf’ is used to notify that the relay node informs the target node about transmitting the data through the relay node when resource requested from reason code of ‘Relay Req’ approved by the relay node. When both the relay device that received the reason code of ‘Relay Req’ and the target device that received the reason code of ‘Relay Ntf’ allow the relay transmission, they send the reason code of ‘Relay Accepted’. If both devices send as the reason code of ‘Relay Accepted’, required relay transmission is only performed.

Table 3. Added Reason Code

Value	Reason Code	Meaning
5	Relay Req	Request of the relay transmission to the relay node
6	Relay Ntf	Notification of the relay transmission to the target node through the relay node
7	Relay Accepted	Approval of DRP resource reservation request for relay transmission

To illustrate the DRP resource reservation protocol of WUSB/DRD/WLP, we describe devices that are used in WLP first. The devices used in WLP can be defined into three functions as a client device, a client bridge, and a remote bridge [7].

Devices with a client function (client devices) are the original source or ultimate destination of data traffic conveyed in WLP frames. Client devices may communicate directly with other client devices that belong to the same WSS. They may also communicate with other client devices and nodes, such as Ethernet stations, by using the services of client bridges.

Devices with a client bridge function (client bridges) forward frames to or from client devices that have requested bridge services. Client devices direct frames to a client bridge in order to communicate with destination nodes reachable through the client bridge. A client bridge and client device must belong to the same WSS for the client bridge to provide bridge services.

Devices with a remote bridge function (remote bridges) offer connectivity between network segments. Remote bridges forward frames to and from other remote bridges, such that each pair of remote bridges creates a new segment bridged to the segments attached to the remote bridges. Remote bridges implement IEEE 802.1D learning bridge mechanisms, and make forwarding decisions using a filter table. Remote bridges implement a spanning tree protocol in order to eliminate redundant paths throughout the network.

A bridge is used for the frame exchange between WLP and wired Ethernet protocol or other similar network protocols. It advertises bridge capabilities in a WLP IE. A neighbor requests bridge services from the bridge in order to initiate the forwarding of frames between the neighbor and other nodes reachable through the bridge.

A bridge could offer connection to other client devices, to nodes reachable through wired or wireless ports using other protocols, or to both. A bridge does not forward frames to or from neighbors that have not registered with it for bridge services. A bridge forwards data frames to and from neighbors that have registered with it for bridge services. A bridge may provide support for establishment of a DRP reservation upon request from a client device. A bridge that supports this feature advertises support in its WLP IE. The request from a client device includes TSPEC information and filtering parameters to identify the expected traffic.

All WLP devices belong to one or more WLP service sets (WSSs) in order to segregate traffic on the medium based on user-controlled membership in the WSSs. WSSs are either secure, to permit traffic to be protected from various passive and active attacks, or non-secure, to permit traffic segregation with no protection from eavesdropping or identity spoofing. Before two devices can exchange data frames, the devices must discover each other, enroll in and activate a common WLP service set (WSS), and establish a connection using the WSS properties. A device may create a new WSS or enroll in an existing WSS at any time. Once a device has created or enrolled in a WSS, it may activate the WSS to communicate with other devices enrolled in the WSS. A device with an activated WSS can connect to any neighbor that has also activated the WSS.

The WLP IE is included in beacons by all devices. It provides information about the device and its participation in WSSs. The format of WLP IE is illustrated in Figure 5.

octets: 1	1	2	2	2	0 or 10	M	N
Element ID (=250)	Length (=6+(0 or 10)+M+N)	Capabilities	Cycle Parameters	ACW/ AnchorAddr	Bridge Information	WSSID Hash List	Broadcast Traffic Indications

Figure 5. WLP IE format

The Capabilities field format of WLP IE is illustrated in Figure 6.

bits: b15-b12	b11-b8	b7-b5	b4	b3	b2	b1	b0
WSSID Hash List Length	Broadcast Traffic Indication Count	Reserved	Discoverable	DRP Establishment	Remote Bridge	Client Bridge	Client Device

Figure 6. Capabilities field format

The DRP Establishment bit is set to one if the device is a bridge and is capable of accepting a DRP reservation request from a client device, or is set to zero otherwise. The Client Bridge bit is set to one if the device can provide bridge services to client devices, or is set to zero otherwise. The Client Device bit is set to one if the device can act as a client device. It is set to zero otherwise.

3. Design of DRP Resource Reservation Cooperative Protocol of WUSB/DRD/WLP

The process of standard DRP reservation negotiation [2] and WUSB DRP reservation negotiation [9] are explained on each protocol, but a cooperative protocol such as WUSB/DRD/WLP has never been defined.

In the WLP protocol described in Section 2, client devices in the same WSS and other protocol device by using client bridge can exchange the frames. That is, if WUSB/DRD and WLP device are the same in WSS, they can communicate by using the client bridge and client device. When they are in different networks, use of the remote bridge solves the problem to communicate. The process of DRP reservation negotiation can be described in the course of the DRP reservation negotiation for WUSB/DRD/WLP using WLP protocol shown in Figure 7.

It is possible to communicate using client devices and the client bridge when WUSB/DRD and WLP device are the same WSS. In order to enable connection to other devices in a WSS, a device must activate the WSS. Prior to activating a WSS, a device must be enrolled in the WSS. To activate a WSS, a device has to include the WSS hash in the WLP IE in its beacon in each superframe. A device may deactivate a WSS by removing the WSS hash from its beacon. In order to enroll in an existing WSS, a device must first discover the existence of another device accepting enrollment for that WSS. A device may use the D1 and D2 frame exchange to discover information about a WSS advertised in a neighbor's WLP IE. During discovery and a subsequent enrollment session, a device that is already enrolled in an existing WSS is referred to as a registrar, and a device seeking to enroll in the WSS is referred to as an enrollee. These roles are temporary and last only for the duration of the enrollment session. A device shall be capable of acting as a registrar. A device shall be capable of acting as an enrollee. To check the WSS properties of a WSS activated by a neighbor, a device sends a D1 association frame to the neighbor. A device does not send a D1 frame to a neighbor unless the Discoverable bit is set to one in the latest WLP IE received from the neighbor. A device that receives a D1 association frame responds with a D2 association frame that contains device information and WSS information, or an F0 association frame that indicates why the discovery request is not accepted or WSS information is not available.

A device may request a bridge to forward frames to or from other nodes by sending a Bridge Services Request control frame to the bridge. A device may also transmit a Bridge Services Request control frame to update protocol or multicast forwarding filters, or to terminate the bridge services requested. Each time a bridge receives a Bridge Services Request control frame from a device, it discards any information retained from previous requests from that device, and use only the information contained in the received request. When a bridge receives a Bridge Services Request control frame, it responds with a Bridge Services Response control frame.

A client device may request a client bridge with which it has enabled bridge services to establish a DRP reservation for traffic addressed to the client device if the bridge indicates support for DRP establishment in its WLP IE. A bridge that supports DRP establishment and receives a DRP Reservation Request control frame establishes a reservation according to the TSPEC field included in the frame, if possible, and report the result in a DRP Reservation Response control frame. The client device establishes a DRP reservation when receiving the response. And if communication between devices is terminated or DRP reservation is completed, the client device deactivates a WSS by removing the WSS hash from its beacon.

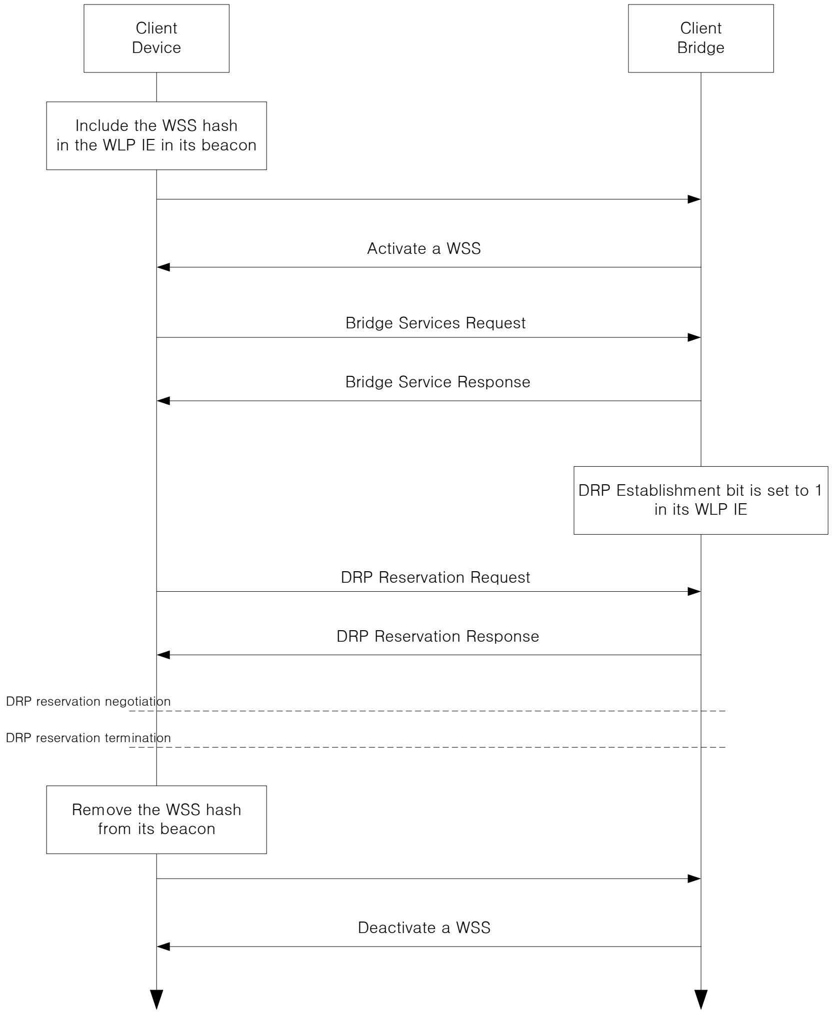

Figure 7. The proposed DRP reservation negotiation of WUSB/DRD/WLP

4. Simulation Results and Discussion

For performance analysis of RNS relay DRP method, we consider the ns-2 simulation environment [10]. Assume randomly distributed devices within 10m x10m and 2048 byte size of packet forwarding. Figure 8 shows the change of performance according to the number of nodes. The Simulation shows that the relay DRP is superior to existing DRP method. With the increase in number of nodes, it shows a better performance. In the case that the number of nodes is increased and failure occurs in the communication between the nodes with the channel condition, it is expected that running the relay transmission through the relay DRP improves the throughput of transmission between the nodes.

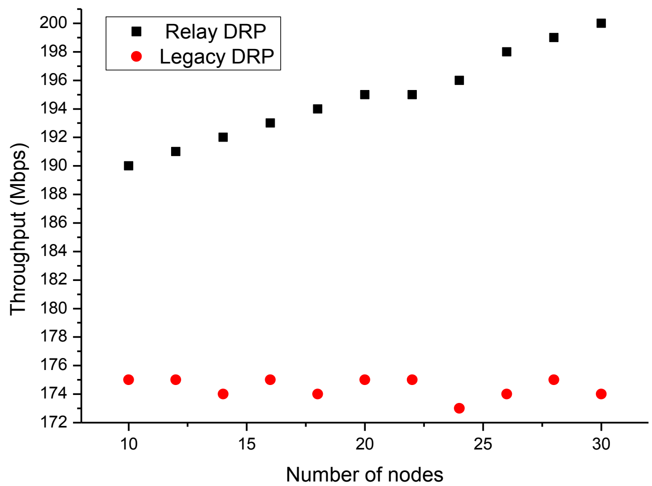

Figure 8. RNS throughput according to the number of nodes

Figure 9 shows the variation of throughput according to the channel environment with 20 nodes. As channel environment is worse, performance decreases. But, in the case of relay DRP, the degree of degradation of performance is reduced compared to the existing DRP. In BER (Bit Error Rate) 10^{-4} to 10^{-3} section of performance of the relay DRP scheme, it is observed degree of performance degradation as compared with the period before. It does not acquire a reliable channel through relay transmission due to changes of the channel environment between all devices. Thus, the throughput of the relay DRP scheme may also be reduced to the same as the existing DRP scheme.

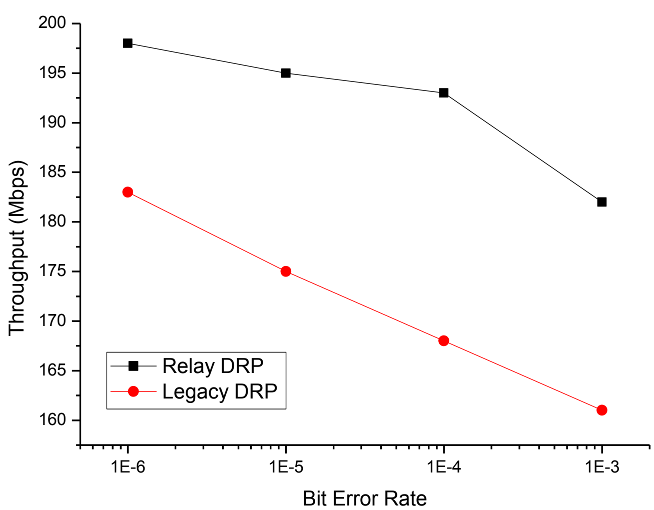

Figure 9. RNS throughput according to the channel environment

5. Conclusion

In this paper, We proposed a cooperative protocol of relay-based WUSB/DRD and WLP devices in a WSS of WiMedia environment. The proposed cooperative protocol can communicate with WUSB/DRD/WLP devices by using the standard DRP reservation and WUSB DRP reservation. We did relay transmission in UWB-based WiMedia using the proposed protocol. And it was confirmed through performance analysis that it is possible to improve the throughput and reduce energy consumption.

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