CHAPTER-1

INTRODUCTION

Wireless USB gives consumers an easy, secure way to connect their PCs, CE, and mobile devices without a cable – without sacrificing speed. Wireless USB enables products from the PC, CE, and mobile industries to connect wirelessly at up to 480 Mbps at 3 meters and 110 Mbps at 10 meters. the requirement of high quality multimedia service in wireless home network environment is more increasing in recent years. WiMedia Alliance has developed the specifications of the PHY, MAC, and convergence layers for UWB (Ultra Wide Band) systems with participation from more than 170 companies. Also, it has been promoting the standardization and adaptation of UWB for HRWPAN(High Rate-Wireless Personal Area Network) that enables the multimedia and high speed data communication[1]. Recently, WiMedia Alliance has completed the specification of WiMedia DMAC(Distributed-MAC) which enables various applications such as WUSB(Wireless USB), Wireless 1394, and Wireless IP, operates on WiMedia D-MAC. The WiMedia D-MAC supports a distributed MAC approach. Fig. 1 shows the relationship between WiMedia protocol and various applications based on UWB.

As shown Figure. 1.1, WUSB is the USB technology merged with UWB based on success of wired USB, and it can be applied to WPAN applications as well as PAN applications like wired USB. Because WUSB specification has defined high speed connection between host and devices for the compatibility with USB 2.0 specification, it can be adapted easily for wired USB applications.

WUSB connects WUSB devices with the WUSB host using a 'hub and spoke' model [2] as shown in figure 1.2. The WUSB host is the 'hub' at the center, and each WUSB device sits at the end of a 'spoke'. Each spoke is a point-to-point connection between the host and device. Like this, the network formed by one host and several devices is referred to as a WUSB cluster. the WUSB host can logically connect to a maximum of 127 WUSB devices, considered an informal WUSB cluster. WUSB clusters coexist within an overlapping spatial environment with minimum interference, thus allowing a number of other WUSB clusters to be present within the same radio cell.

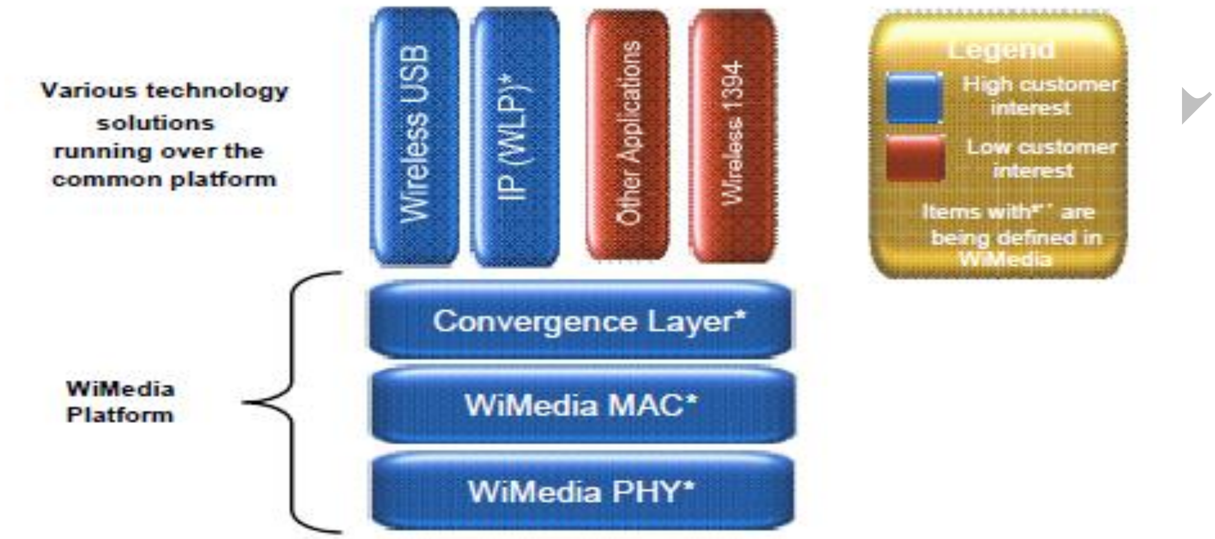

Figure 1.1:UWB Protocol Relationships.

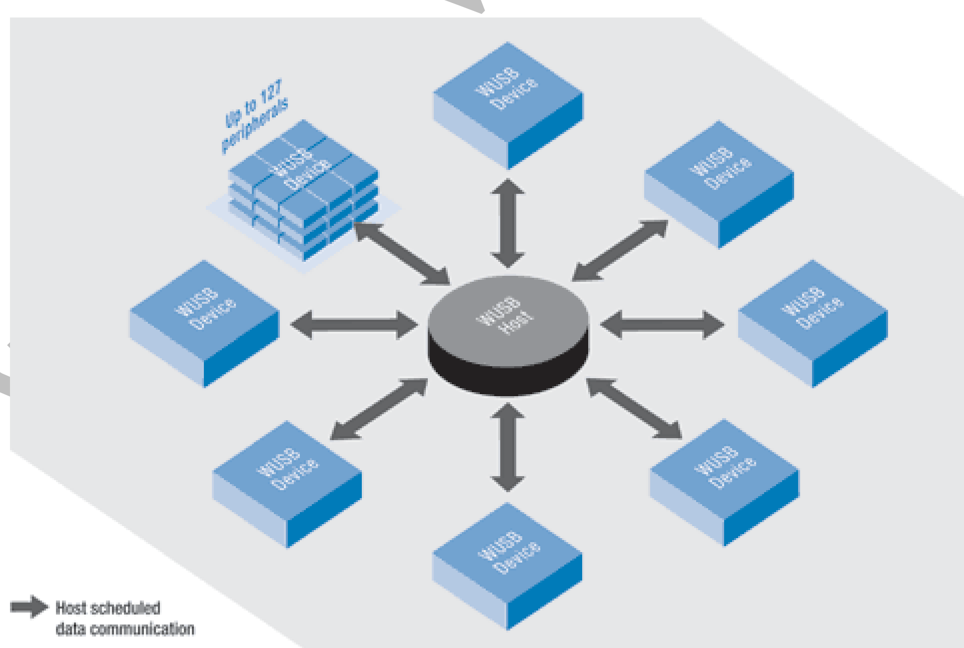

Figure 1.2 WUSB Hub and Spoke Topology

There is only one host in any WUSB cluster and WUSB host performs to transmit/receive a data with WUSB devices in the WUSB cluster. Also, it schedules the exchange of data between WUSB host and WUSB devices and allocates time slots to WUSB devices in its own cluster.Because of its wireless property, WUSB protocol must consider the mobility of WUSB host and devices. However, the current WUSB protocol does not support mobility of the WUSB host. Thus, in the WUSB home network environment, the Private DRP (Distributed Reservation Protocol) conflict can frequently occur by the mobile WUSB host. In this paper, we focus on mobility support for DRP-based isochronous stream in the WUSB protocol, and we propose a Private DRP conflict prevention scheme.

In the proposed scheme, a new GetStatus(Extended MAS Availability) is proposed. And then, by using the information in Extended DRP Availability IEs from received beacons, a proposed Private DRP reservation negotiationprocess is newly executed at each WUSB device to avoid the hidden DRP reservation conflicts by the mobile WUSB host. By using this proposed method, we can make the current WUSB protocol complete and scalable through preventing the frequent hidden DRP reservation conflicts caused by mobile WUSB host and devices.

CHAPTER 2

THE DATA FLOW IN WUSB PROTOCOL

WUSB utilizes the WiMedia MAC Layer and PHY which define several methods for using the MAC Layer resource, including Distributed Reservation Protocol (DRP) based on TDMA to support the QoS.

WUSB defines a WUSB Channel which is encapsulated within a WiMedia MAC superframe via private DRP reservation blocks. The WUSB Channel is scheduled by a continuous sequence of linked application-specific control packets, called MMCs (Micro-scheduled Management Commands), which are transmitted by the WUSB host within the private DRP reservation blocks. The Microscheduled Management Command (MMC) is the fundamental element of the Wireless USB protocol. MMCs are used to help devices discover information about a WUSB cluster, notify their intentions, manage power, and schedule data transmissions efficiently to obtain very high throughputs [2]. Figure. 2.1 shows the relationship between WiMedia MAC and WUSB.

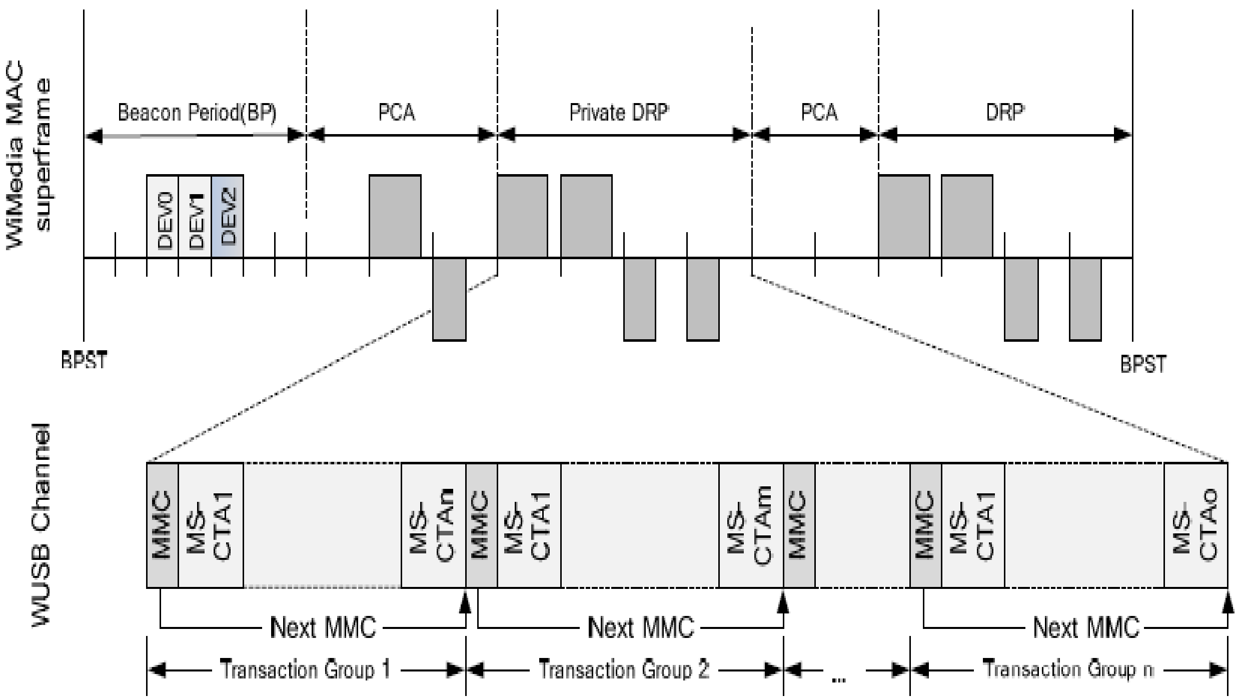

Figure.2.1 The example of the data exchange between WUSB devices through WiMedia D-MAC.

A WUSB host is required to implement the WiMedia MAC protocol, establish and maintain WUSB Channels by allocating sequences of private DRP reservation in WiMedia MAC. A WUSB device may implement the full WiMedia MAC protocol; however it is nominally only required to implement the WUSB protocol which operates within the WUSB Channel

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2.1. Private DRP conflict resolution of the current WUSB standard

As mentioned above, a WUSB host must include a DRP IE in their beacon frames to protect the WUSB Channel. When a WUSB host becomes active, it must choose a PHY channel in which to operate the WUSB channel. Once the host is beaconing then it establishes a WUSB Channel by private DRP reservation for WUSB data communications. In this case,WUSB host is the DRP reservation owner, and WUSB device is the DRP reservation Target. Thus, WUSB device must be able to determine which MASs (Medium Access Slots) are available for communication with the WUSB host. Since there are various WiMedia devices in the WUSB cluster.

The WUSB device identifies the WUSB host's DRP IE based on the following keys:

- Reservation Type field is Private.
- Stream Index field has the value of the WUSB Channel's stream index.
- Owner DevAddr field set to the WUSB Channel's Broadcast Cluster ID.

The WUSB device identifies a cluster member's DRP IE based on the following keys:

- Reservation Type field is Private.
- Stream Index field has the value of the WUSB Channel's stream index.
- Owner DevAddr field set to the WUSB host's DevAddr.

Figure 2.2 shows the current operation of DRP reservation in WUSB protocol. A WUSB host uses the GetStatus(MAS Availability) MMC request to retrieve a device's MAS Availability information. A WUSB device that has received the GetStatus(MAS Availability) MMC request from the WUSB host accumulates the information from its neighbors' beacons about available MASs. Then, the WUSB device responds to the GetStatus(MAS Availability) MMC request through the bmMASAvailability (MAS Availability) field.

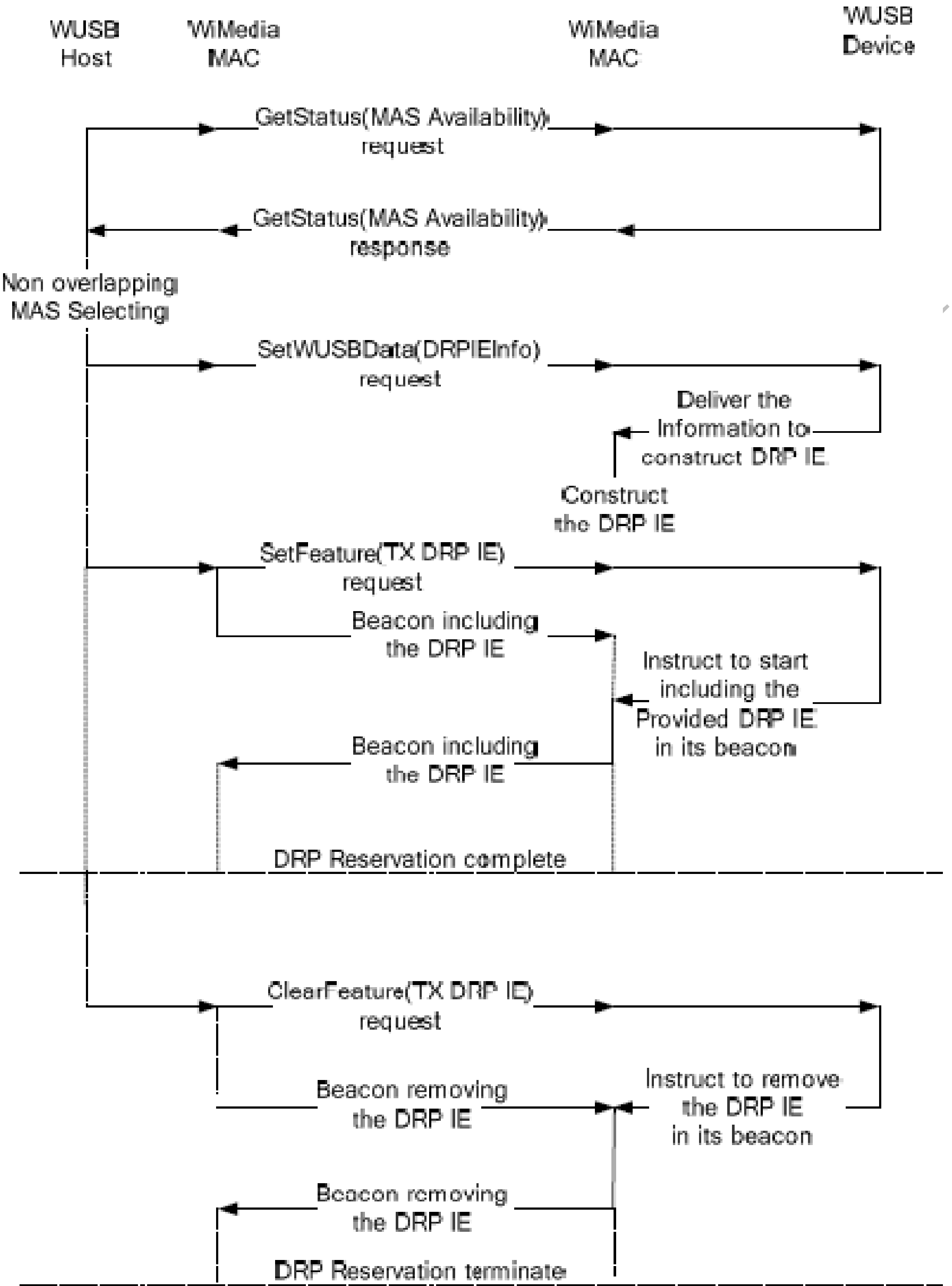

Figure 2.2 The Current Operation of DRP reservation in WUSB Protocol.

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Figure .2.3 shows the format of the GetStatus request. bmMASAvailability field is a 256-bit map, where each bit location corresponds to a MAS slot in the WiMedia D-MAC Layer superframe. A 1B in a bit location means that the device is available for a reservation in the corresponding MAS slot. A 0B indicates the corresponding MAS slot is not available.

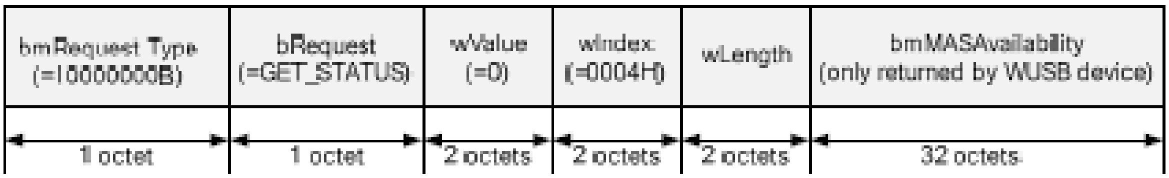

Figure 2.3 .The format of the GetStatus(MAS Availability) request.

After the WUSB host that has received WUSB device's response selects available MASs, it transmits a SetWUSBData(DRP Info) request. The SetWUSBData(DRP Info) is used to construct the DRP IE (Information Element) that the WUSB device transmits in its beacon. If the WUSB device does not have an existing DRP IE for this Wireless USB Channel, it simply adds the received DRP IE to its beacon. If the device has an existing DRP IE for this Wireless USB Channel, then it must replace the existing DRP IE with the new DRP IE provided in this command payload.

Figure 2.4 shows the format of SetWUSBData(DRP Info) request. The values of bmAttributes field are used to construct the DRP Control field of a DRP IE in the WiMedia D-MAC. The Conflict Tie-breaker bit is set to a random value of zero or one when a reservation request is made, and it is used for DRP conflict resolution. DRP IE Data field is the DRP Allocation blocks that must be included in the DRP IE transmitted by the device.[2]

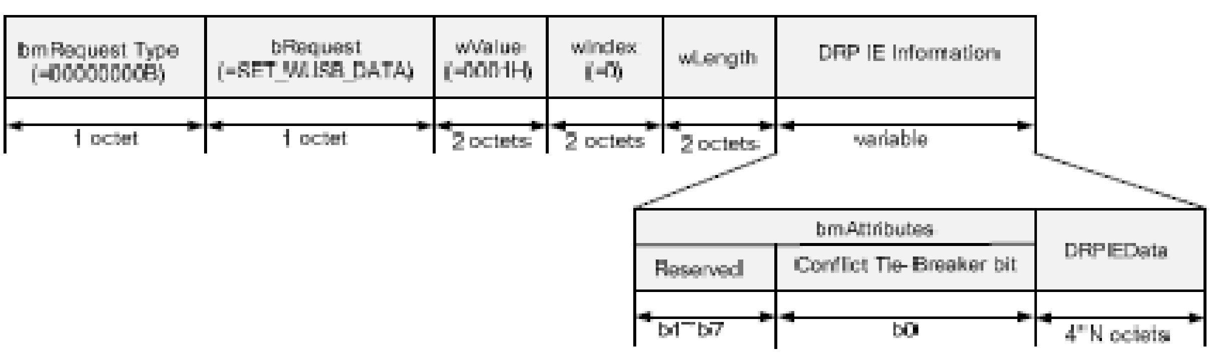

Figure 2.4. The format of the SetWUSBData(DRP Info) request.

If the WUSB host transmits the SetFeature(TX DRP IE) request to the WUSB device, the WUSB device starts the transmission of its beacon including DRP IE set to the values in DRP IE Information field. Figure 2.5 shows the format of SetFeature(TX DRP IE) request. To terminate the DRP reservation, WUSB host uses a ClearFeature(TX DRP IE) request. It instructs a WUSB device to cease transmitting the DRP IE in its beacon. Figure 2.6 shows the format of ClearFeature(TX DRP IE) request.

bmRequest Type (=00000000B)	bRequest (=SET_FEATURE)	wValue (=WUSB_DEVICE)	wIndex (=TX DRP IE)	wLength (=0)
1 octet	1 octet	2 octets	2 octets	2 octets

Figure 2.5. The format of the SetFeature(TX DRP IE) request.

bmRequest Type (=00000000B)	bRequest (=CLEAR_FEATURE)	wValue (=WUSB_DEVICE)	wIndex (=TX DRP IE)	wLength (=0)
1 octet	1 octet	2 octets	2 octets	2 octets

Figure 2.6. The format of the ClearFeature(TX DRP IE) request

Figure 2.7 shows an example of current resolution of 2-hop range private DRP reservation conflicts. In Fig. 8, a DRP reservation DRPH1 has been established between WUSB host H1 and WUSB device D1. H1 transmits data frames to D1 during the DRPH1 period. If WUSB host H2 begins to reserve MAS with WUSB Device D2 to transmit data frames to D2 during DRPH2 period with overlapping MASs, a DRP conflict happens between DRPH1 and DRPH2. In the WUSB, this problem is solved by bmMASAvailability. If H1 and D1 success the DRPH1 MAS reservation, D1 broadcasts the information about DRPH1 period by transmitting its SetFeature(TX DRP IE). From information of received D1's SetFeature(TX DRP IE), D2 marks DRPH1 period as unavailable in its bmMASAvailability field. The bmMASAvailability field in GetSatus(MAS Availability) is used by a device to indicate its view of the current utilization of MASs by 1-hop neighbors in the current superframe. A device's bmMASAvailability field is made by receiving and combining SetFeature(TX DRP IE) requests from its 1-hop range neighbor devices. If H2 receives the GetStatus(MAS Availability) from D2, then, the H2 can know that the DRPH1 period is unavailable for D2. And in reserving DRPH2 period, it excludes those MAS belonging to the DRPH1 period. Therefore, DRP reservation conflicts between the 2-hop range hidden devices (i.e. D1 and H2) are prevented by transmitting the GetStatus(MAS Availability). In Figure 2.6, the case where H2 receives the GetStatus(MAS Availability) from D2 means that the H2 receives information of 2-hop range devices' DRP reservation status.

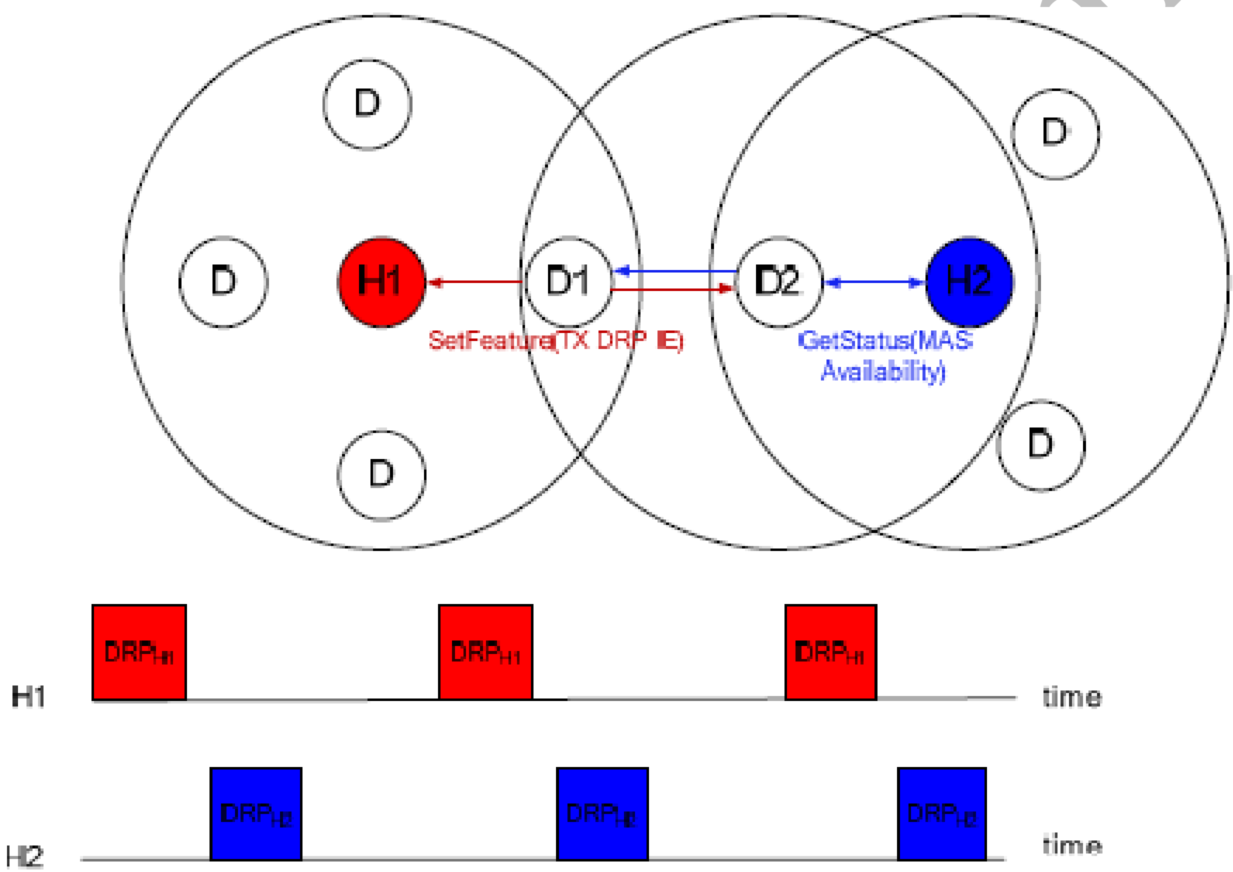

Figure 2.7 Example for the current resolution of 2-hop range DRP reservation conflicts

2.2 **Problem of the current MAS reservation method in the WUSB protocol.**

As mentioned in the previous subsection, in the conventional WUSB, there is no DRP reservation conflict between WUSB host and devices having two-hop distance. However, there is no consideration of DRP reservation conflicts between WUSB host and devices having 3-hop distance. In Figure 2.8, a MAS reserved by a WUSB host H1(DRPH1) in the WUSB cluster 1 is likely to be used by a WUSB device D3(DRPH3) in the WUSB cluster 3 having 3-hop distance from that WUSB host H1. But, in this situation, if that D3 moves and comes into the one-hop transmission range of the D1, the reserved MASs by the newly entering D3(DRPH3) can be overlapped with the reserved MASs by the H1(DRPH1), which causes a problem of 3-hop range hidden DRP reservation conflicts. Figure 2.8 explains this situation where a 3-hop range hidden DRP reservation conflict occurs.

In Figure 2.8, the D3 has a 3-hop distance with the H1. So, a DRPH1 period can have the same MASs which are also reserved during DRPH3. Because each DRP data transmission is out of range, four devices (H1, D1, D2, D3) can exchange data frames without interference. However, in Figure 2.9, when the D3 moves into the D1's range with its own reserved MASs, two reservations, DRPH3 and DRPH1, can have a DRP reservation conflict.

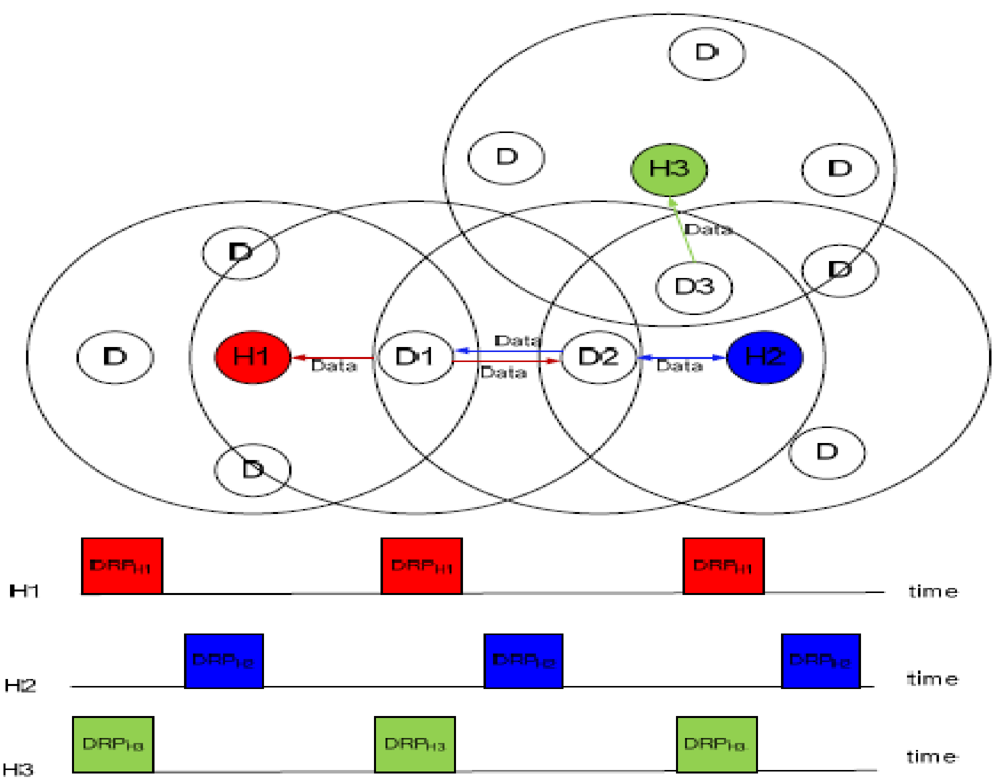

Figure 2.8. Interference-free data transmission during each DRPH1 and DRPH3.

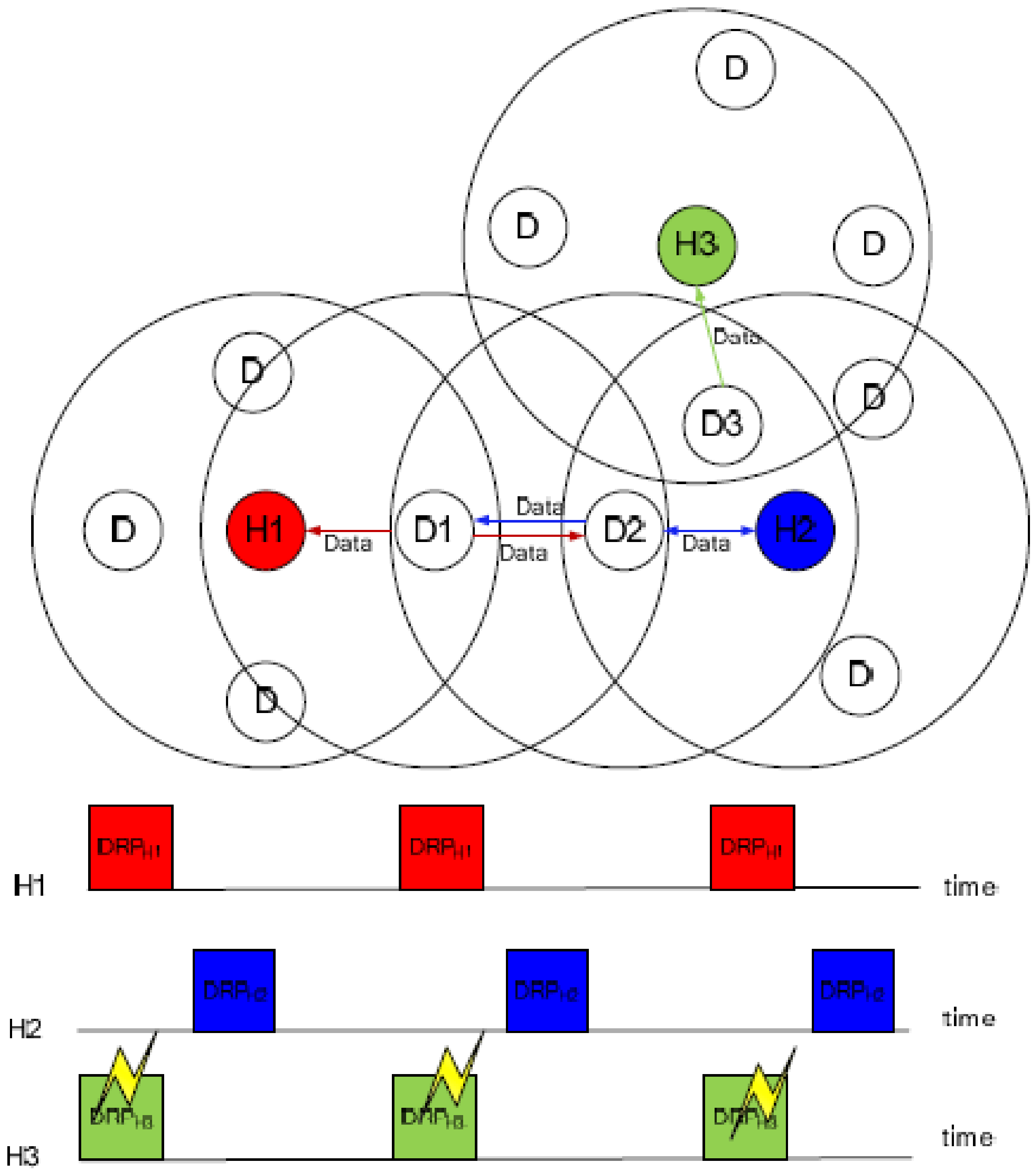

Figure 2.9 A 3-hop range DRP conflict due to the mobility of D3

CHAPTER 3

PROPOSED 3-HOP RANGE DRP CONFLICT PREVENTION METHOD

In this Section, they propose a prevention scheme for 3-hop range private DRP conflicts. The proposed scheme utilizes a new GetStatus(Extended MAS Availability) request, and need a new private DRP negotiation procedure

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3.1 GetStatus(Extended MAS Availability)

Once a 3-hop range DRP conflict occurs, the only one DRP reservation among all reservations involved in that conflict maintains the reserved DRP period and the other DRP reservations must be terminated to restart DRP negotiations although those DRP reservations may have only a few overlapping MASs. So, this 3-hop range DRP conflict makes the channel utilization performance degrade severely. However, if a WUSB host can know the information of its 3-hop range hidden private DRP reservation status, it can avoid use of overlapping MASs. That is, we can prevent the 3-hop range DRP conflicts. To that purpose, we propose a new GetStatus(Extended MAS Availability) which is made by receiving and combining all DRP IEs from its neighbor WUSB devices. So, it is used by a device to indicate its view of the current reservation status of MASs by its 2-hop range devices (e.g. between D1 and D3 in Fig.2.8 and 2.9) in the current superframe.

In Figure 3.1, the bmExtendedMASAvailability bitmap field is up to 256 bit long, where each bit location corresponds to a MAS slot in the WiMedia D-MAC Layer superframe. Each bit is set to ‘one’ if the corresponding MAS is available for a DRP reservation in 2-hop range area from the device, or each bit is set to ‘zero’ otherwise. When using GetStatus(Extended MAS Availability), we need a new DRP negotiation procedure.

bmRequest Type (=10000000B)	bRequest (=GET_STATUS)	wValue (=0)	wIndex	wLength	bmExtendedMASAvailability
1 octet	1 octet	2 octets	2 octets	2 octets	32 octets

Figure 3.1 The format of GetStatus(Extended MAS Availability)

3.2 New 3-hop range private DRP reservation process

The DRP reservation negotiation process is always initiated by the WUSB host that will initiate frame transactions in the reservation. To start new private DRP reservation process, a WUSB host uses the GetStatus(MAS Availability) request to retrieve a device's MAS Availability information. A WUSB device that has received the GetStatus(MAS Availability) request from the WUSB host accumulates the information from its neighbors' beacons about available MASs. Then, the WUSB device responds to the GetStatus(MAS Availability) request through the bmMASAvailability (MAS Availability) field. A WUSB host that has received the GetStatus(MAS Availability) responses from WUSB devices transmits the GetStatus(Extended MAS Availability)request to collect the information of its 3-hop range hidden private DRP reservation status. A WUSB device that has received the GetStatus(Extended MAS Availability) request from the WUSB host accumulates the information of private DRP reservation status of its 2-hop range neighbors from its neighbors' beacons about available MASs. The WUSB host that has received the WUSB devices' responses for GetStatus(Extended MAS Availability) selects non overlapped MASs based on the MAS reservation information provided by GetStatus(MAS Availability) and GetStatus(Extended MAS Availability) responses. After selecting non overlapped MASs, it transmits a SetWUSBData(DRP Info) request to provide the WUSB devices with the information of DRP IE to be included in its beacon. After transmitting a SetWUSBData(DRP Info), the WUSB host transmits the SetFeature(TX_DRPIE) for WUSB devices to disignate including the DRP IE in their beacons. If the WUSB device does not have an existing DRP IE for this Wireless USB Channel, it simply adds the received DRP IE to its beacon. If the device has an existing DRP IE for this Wireless USB Channel, then it must replace the existing DRP IE with the new DRP IE provided in this command payload.

To terminate DRP reservation, the WUSB host uses the ClearFeature(TX_DRPIE). Figure 3.3 explains the operation of new private DRP reservation procedure.

In the proposed private DRP negotiation procedure, we just added some steps in which the WUSB host device selects a 3-hop conflict-free MAS block according to its and the DRP Target device's 2-hop DRP Availability IEs. Based on the proposed private DRP negotiation procedure, Figure 12 shows a WUSB scenario where a possible 3-hop range private DRP reservation conflict between DRPH1 and DRPH2 in Fig.2.7 is certainly prevented

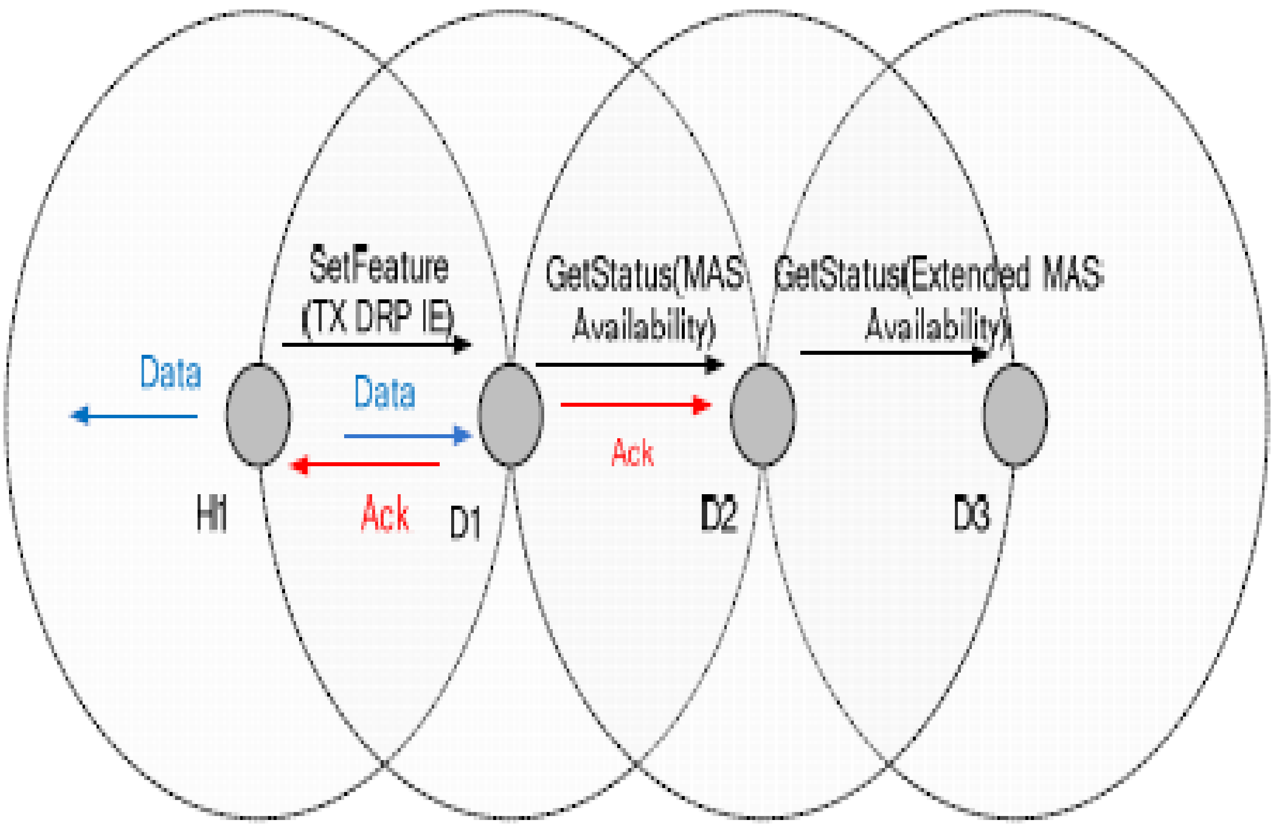

Figure 3.3 Propagation of 3-hop range DRPH1 reservation information from H1 to D3

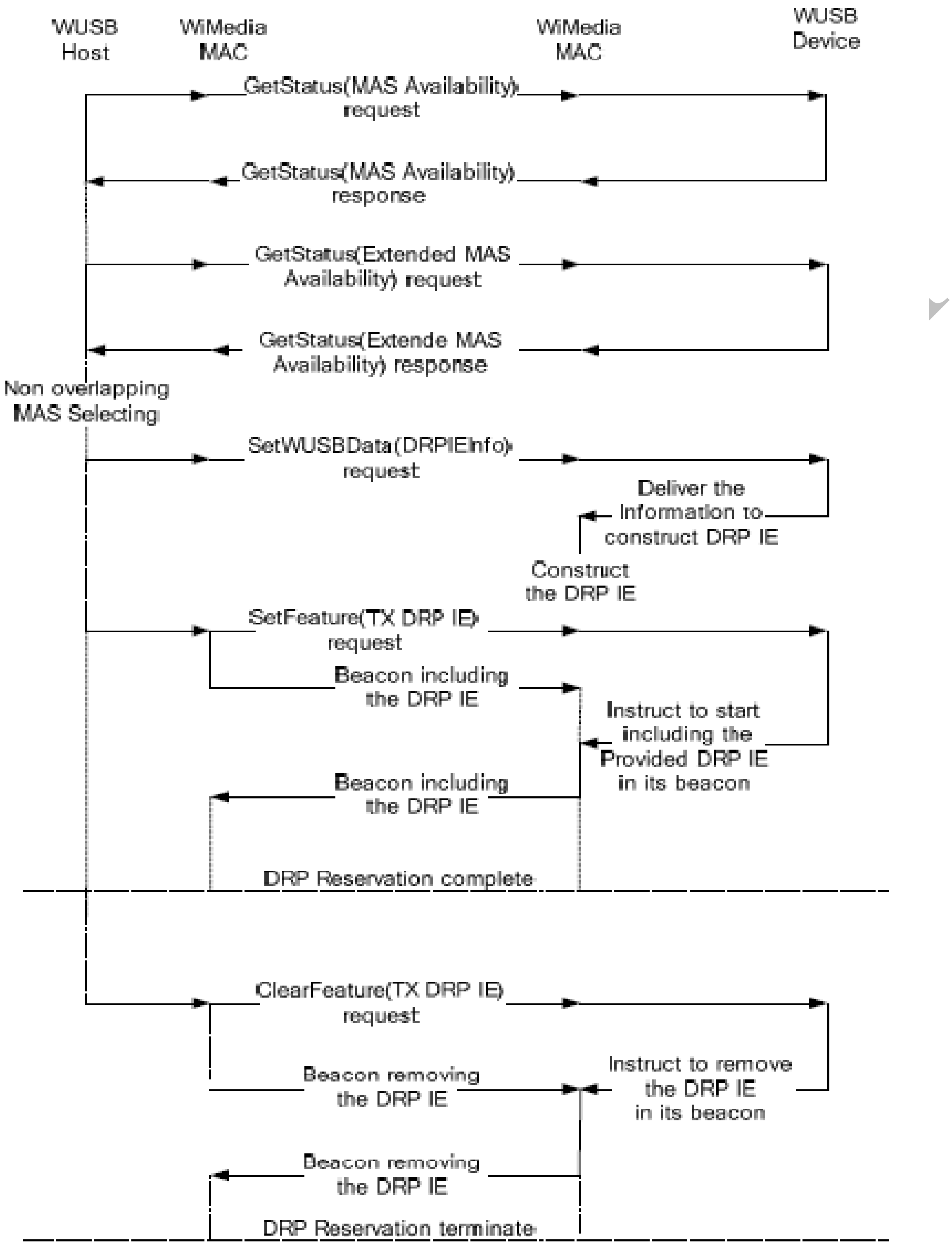

Figure 3.2 Operation of new private DRP reservation process in WUSB Devices.

CHAPTER 4

PERFORMANCE EVALUATION

Performance of the proposed scheme is evaluated through NS-2 simulations. Table 1 shows the simulation parameters used in this paper; the network size is 10m*10m; the maximum 20 devices are randomly deployed into this area. For this simulation, we denote a number of MASs in own DRP reservations of the reference WUSB device as DRPown. And a number of MASs in private DRP periods reserved by 1-hop neighbor devices of the reference device is denoted as L1-hop. Also, a number of MASs in private DRP periods reserved by 2-hop distant devices from the reference device is denoted as L2-hop. Finally, a number of MASs in private DRP periods reserved by 3-hop distant hidden devices from the reference device is denoted as L3-hop. On the other hand, each WUSB device has two kinds of mobility with each corresponding probability such as mIn and mOut. The mIn means a probability with which a WUSB device moves into a 1-hop closer range of the reference device, such as it moves from 3-hop to 2-hop range. And mOut means a probability with which a device moves into a 1-hop outer range of the reference device, such as it moves from 2-hop to 3-hop range.

Parameter	Value
$L_{1\text{-}hop}$	30MASs
$L_{2\text{-}hop}$	30MASs
$L_{3\text{-}hop}$	20MASs
DRP_{own}	20MASs
m_{Out}	0.2

TABLE 1: SIMULATION PARAMETERS

Figure 4.1 shows throughputs of a WUSB device according to each UWB/PHY data rate for each mIn probability. In Figure 4, the frame size transmitted by devices in a beacon group is fixed to 4095 bytes. These results show that the more mIn mobility of devices increases, throughput of a device the more decreases. This is because the increase of mIn probability of devices causes more 3-hop hidden private DRP reservation conflicts, as is explained in Figure 2.7 In other words, this results show that how much the 3-hop private DRP conflict prevention method improves throughput of a WUSB device.

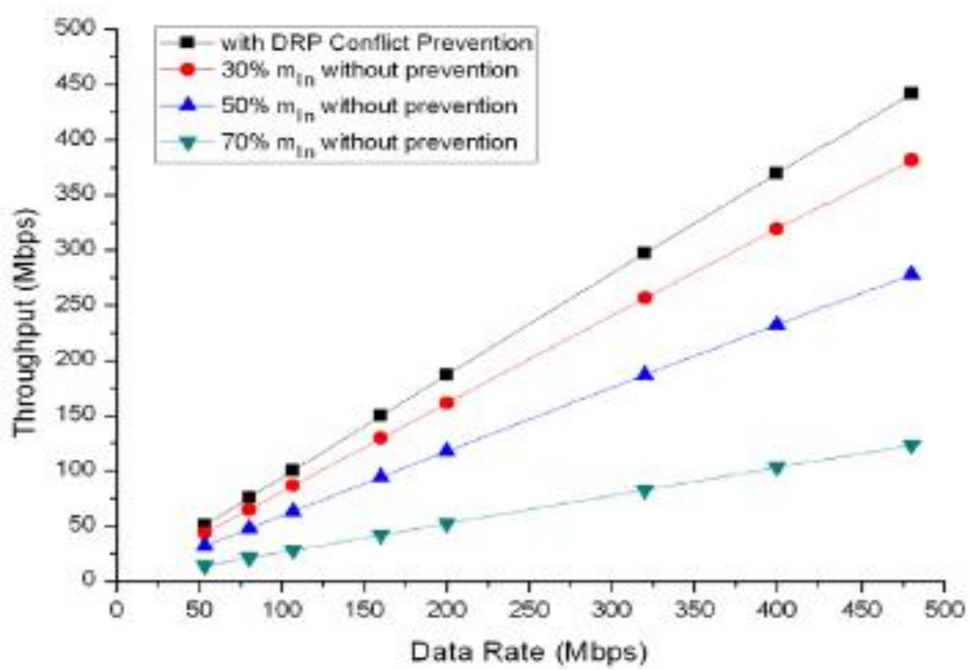

Figure 4.1 Throughput of a WUSB device according to each UWB PHY data rate.

And, Figure 4.2 shows the relationship between throughput of a WUSB device and the frame size transmitted. In Figure 4.2 the UWB PHY data rate of devices is fixed to 480Mbps. As shown in Figure 4.2 the throughput of WUSB devices doesn't vary largely according to the frame size after the frame size exceeds a certain threshold. Because the transmission in DRP reservation blocks is performed without contention, the increase of frame size doesn't cause an increase of probability of frame collisions. But the throughput of WUSB device decreases extremely and proportionally according to the value of mIn probability because the movement of WUSB devices can directly cause the 3-hop private DRP reservation conflicts.

Figure 4.3 shows 3-hop hidden private DRP reservation conflict probability according to each L3-hop amount of 3-hop hidden DRP reservations. In Figure 4.2, if the amount of L3-hop is larger, the 3-hop hidden private DRP reservation conflict probability increases rapidly. If we assume a general mIn probability value as 30%, this figure shows that the 3-hop private DRP conflict probability is affected largely by the L3-hop even though the value of L3-hop isn't large. Therefore, we must consider seriously this 3-hop private DRP reservation conflict problem for development of the WUSB technology.

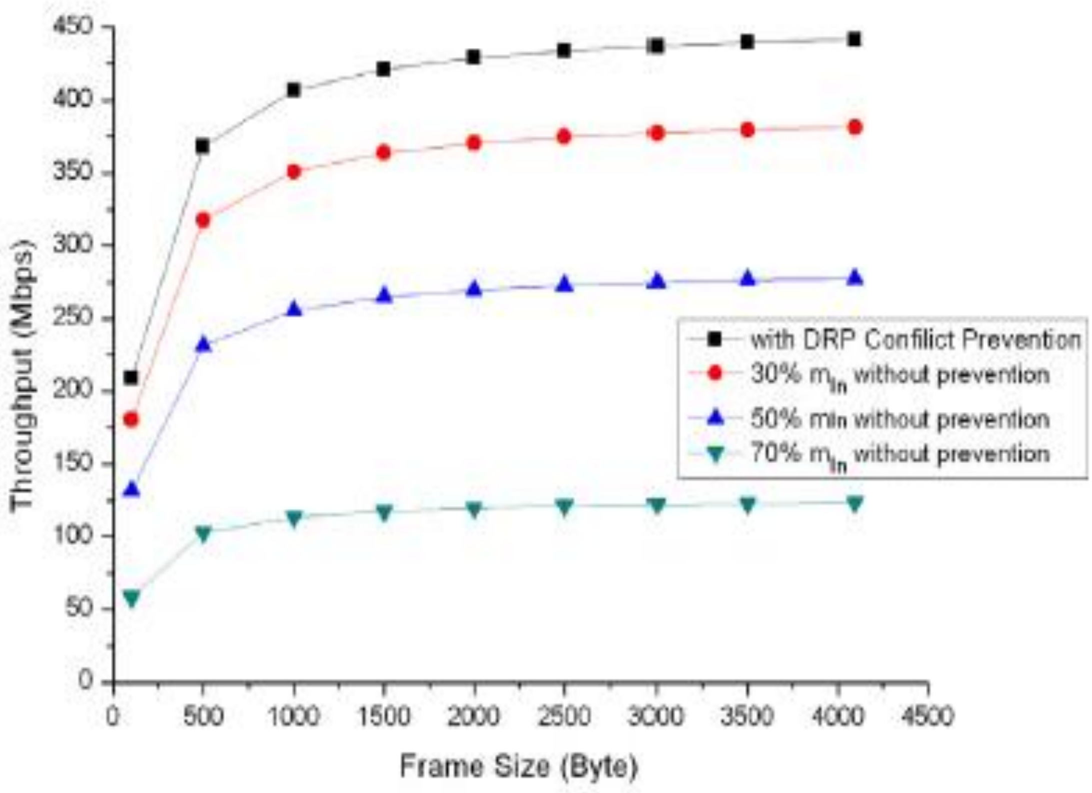

Figure 4.2 Throughput of a WUSB device according to each frame size.

Finally, Figure 4.4 shows the relationship between the 3-hop private DRP Conflict Probability and the mIn probability of a WUSB device according to the mOut probability. As shown in Figure 4.3, mOut probability doesn't affect largely the 3-hop DRP conflict probability because the movement into 1-hop inner range of a WUSB device causes the 3-hop private DRP reservation conflict with the device's own DRP reservation as is explained in Fig. 9.

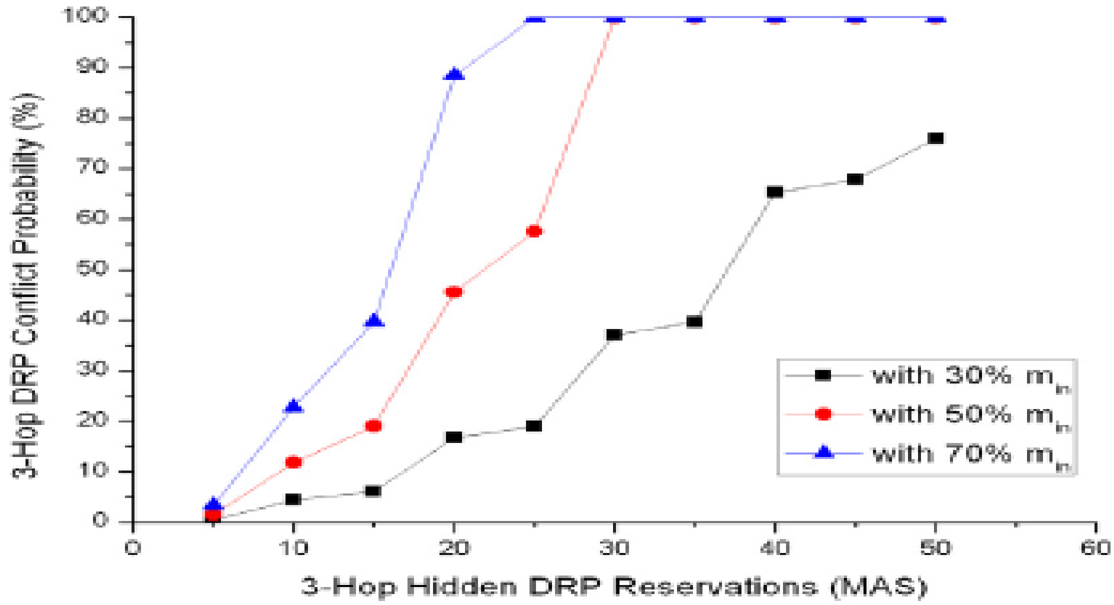

Figure 4.3 3-hop DRP Reservation Conflict Probabilities according to each amount of 3-hop Hidden private DRP Reservations

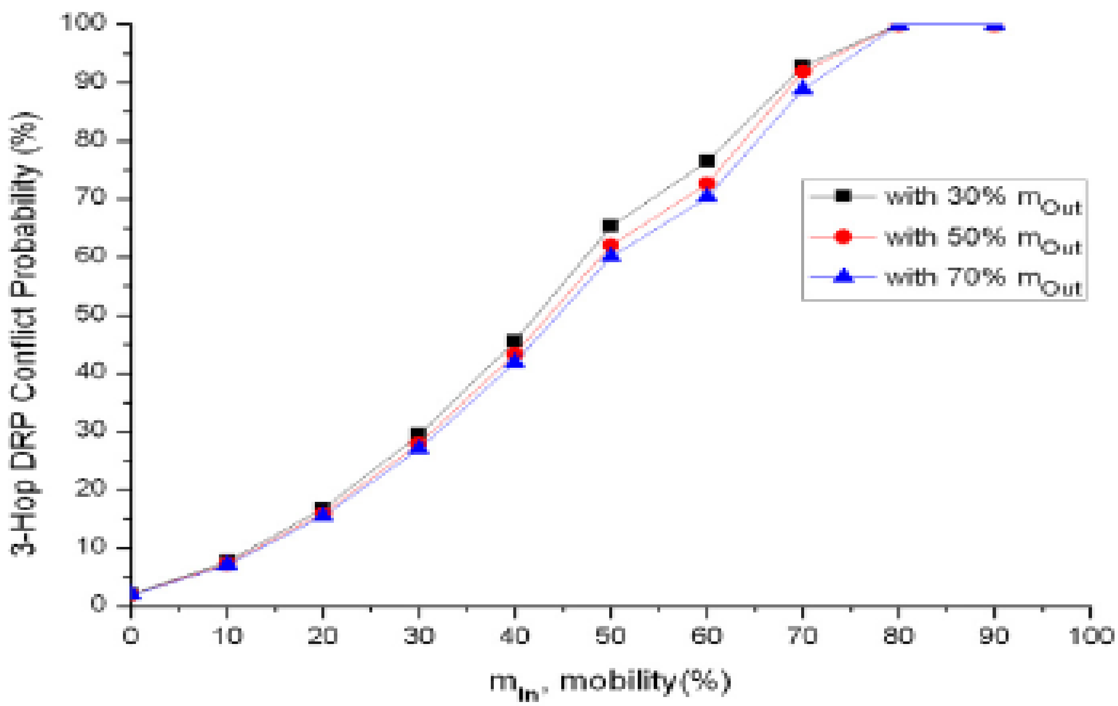

Figure 4.4 3-Hop private DRP Conflict Probabilities according to each mIn probability.

CHAPTER 5

CONCLUSION

The WUSB technology has been considered as the most powerful solution for Home Networking due to its mobility support, high data rate, and reliability. But the current DRP reservation scheme in WUSB protocol can’t solve the private DRP reservation conflicts between mobile devices having 3- hop distance. Such a drawback of the current WUSB protocol degrades throughput performance more severely in mobile networking environment. Furthermore, it obstructs the scalability for large scale networks. In this paper, by using a new GetSatus(Extended MAS Availability), we propose a new method to prevent private DRP reservation conflicts that frequently happens among WUSB hosts/devices having 3-hop distance. The simulation results show that our prevention method supports 3-hop mobility and it largely increases throughputs of devices at frequent 3-hop range private DRP reservation conflicts.

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