

An Efficient Network Merging Mechanism for WiMedia UWB MAC Protocol

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Abstract— WiMedia UWB MAC protocol defines to use wide bandwidth and low power to communicate data for high speed in short range. WiMedia UWB MAC configures a fully distributed beaconing network based on non-infrastructure and devices broadcast their beacons through each beacon slot in a superframe which is made up of 256 MAS. Due to changes in the propagation environment, mobility, or other effects, devices using two or more unaligned BPSTs may come into range. This situation causes synchronization problem which is solved by merging two networks with different BPSTs. Although they make progress for merger, they don't have any criterion about a network to move. Therefore merging process of WiMedia MAC is inefficient. In this paper, we propose a criterion for an efficient network merger mechanism for WiMedia UWB MAC Protocol and demonstrate good performance of our scheme by simulation.

Keywords— Wimedia UWB MAC, Beacon, Merger

I. INTRODUCTION

Ultra wideband (UWB) technologies are being rapidly developed in the technical community and will enable extremely high rate, short-range wireless networks. UWB devices are expected to operate at rates of up to 400 Mb/s and communicate with other devices at a range of up to 10 m, thus enabling high-speed wireless personal area Networks (WPANs) [1]. The name ultra wideband derives from the wide swath of spectrum used for communication in relation to the central frequency. UWB is the next wireless networking technology to appear on the market, poised to repeat the successes of Bluetooth and Wi-Fi. This explosive growth in the wireless industry in a short time is attributable to the Federal Communications Commission's (FCC's) approach allowing more and more unlicensed bands. UWB devices are allowed to operate in an unlicensed manner in the 3–10 GHz band, with low permitted transmit power. Due to the low transmit power, UWB devices do not cause harmful interference, and therefore coexist with other users in the same band. A large industry consortium now known as WiMedia Alliance is developing these specifications. The MultiBand OFDM alliance (MBOA) [2], which was originally formed to define an OFDM-based PHY layer

specification, merged with the WiMedia alliance to form a single organization, known by the latter name, that is currently specifying the PHY, MAC, and convergence layers for UWB systems. The WiMedia MAC [3] architecture is completely distributed. It does not require a central controller for operation. In order to better understand the remaining sections, we need to introduce the concepts of beacon group and extended beacon group. In a network formed with fully distributed medium access coordination, logical groups are formed around each device to facilitate contention-free frame exchanges while exploring medium reuse over different spatial regions. A beacon group is defined as a set of devices from which a device receives beacons that have the same BP start time (BPST) as the device. The extended beacon group is the union of a device's beacon group and the beacon groups of all devices in the device's beacon group [4, 5]. This is shown in Fig. 1.

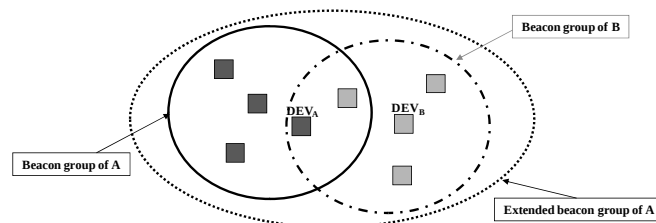


Fig. 1 The extended beacon group

In this paper, we propose an efficient merger mechanism. The paper is organized as follows. In Section II, we introduce about WiMedia UWB MAC protocol. Our proposed mechanism discussed in Sections III. Section IV shows the simulation results. Finally, Section 5 concludes this paper with future works.

II. OVERVIEW OF THE WIMEDIA MAC PROTOCOL

In WiMedia MAC, medium time is divided into superframes, which describe periodic intervals used to coordinate operation between devices. A superframe is divided into two parts: a beacon period (BP) followed by a data transfer period (DTP). The superframe is a periodic interval of time with duration of 65.536 ms. The superframe is divided into slots; in total there are 256 medium access slots (MASs), where each MAS

duration is 256 μ s. Each superframe starts with a BP. The start of the first MAS in the BP, and the superframe, is the BPST. The remaining MASs in the superframe are used for data transmission using DRP or PCA [6]. The superframe structure is shown in Fig. 2.

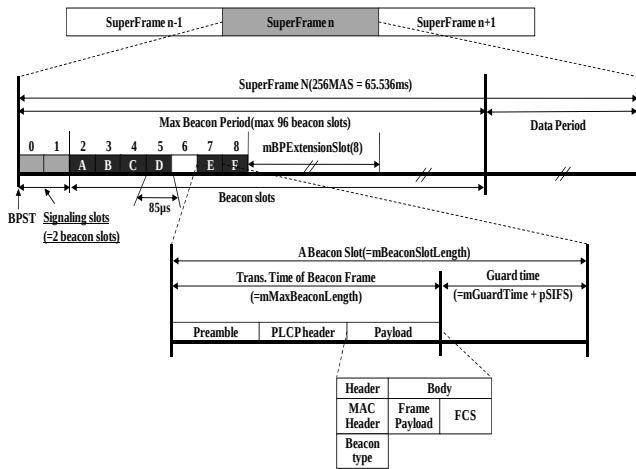


Fig. 2 Superframe structure of WiMedia MAC

Every WiMedia device sends a beacon during the BP. The BP extends over one or more MASs; its length is variable, depending on the number of devices within range. Since the MAC protocol is distributed, there is no concept of global BP. That is, a device observes its own BP with its own BPST and BP length, which depends on the number of devices within its extended beacon group.

The BP is divided into beacon slots of 85 μ s. Each device chooses a beacon slot for transmission of its beacon frame. Information included in a beacon frame is coded as information elements (IEs). Different IEs are defined for different functions. For example, the traffic identification map (TIM) IE includes a list of devices for which the device has buffered traffic; the Distributed Reservation Protocol (DRP) IE includes information regarding a reservation of the superframe time in units of MAS; the hibernation IE contains information about the power saving state of the device. A device may send a beacon frame with one or more IEs, making the length of a beacon frame also variable (but with a limit called aMaxBeaconLength to fit into a beacon slot).

Before any transmission, a device shall scan for beacons for at least one superframe, or at least two superframes if no beacon frame is received. If device cannot receive up to two beacon frame, it will create a new BP, in which it will send a beacon in the first beacon slot after the signaling beacon slots. Otherwise, if a device hears one or more beacon frame header from other devices during the BP, it will not create a new BP, but execute join procedure. At this time, if the device receives one or more frame headers, but no beacon frames with a valid FCS during the scan, the device should scan for an additional superframe. If the device receives one or more beacon frame with valid FCS, it transmits its own

beacon to current superframe for join the beacon group. Fig. 3 describes beacon scanning procedure.

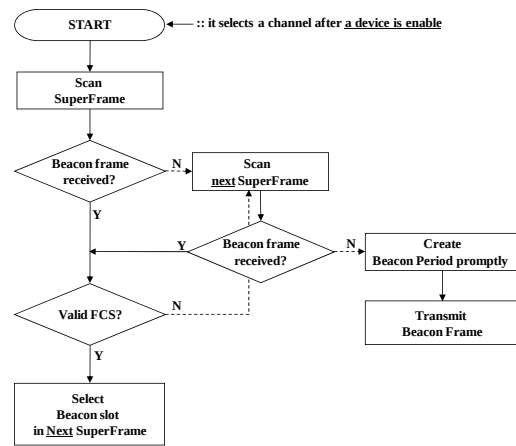


Fig. 3 Beacon period structure

One of the most important IEs is the BP occupancy IE (BPOIE). The BPOIE contains a list of devices in the device's beacon group. The BPOIE is used to update the device's BP length and detect beacon collisions. A beacon collision occurs when two or more devices in a device's beacon group send beacons in the same beacon slot. To avoid beacon collisions, devices within two-hop radio range must use different beacon slots. However, devices that are more than two hops apart may use the same beacon slot, thus enabling spatial reuse of beacon slots. To minimize the probability of beacon collisions, a device scans for beacons from other devices once it is turned on. If one or more beacons are received correctly during the initial scanning, the device determines which beacon slots are available. If no beacon is received during the initial scanning, the device creates its own BP. In general, a device chooses the beacon slot after the currently highest-numbered occupied slot in the BP. Once a beacon slot is chosen, the device always sends the beacon frame in the same slot, unless a beacon collision occurs. A beacon collision is detected and resolved as follows. Every time a beacon from a device in the beacon group is received correctly, the device records the device address (DevAddr) of the beacon transmitter. This information is included in the BPOIE in the next superframe. If a device's own DevAddr is not included in the BPOIEs received from neighbors' beacons, the device can conclude that a collision or transmission error may have occurred. If this continues for multiple superframes, the device concludes that its beacon is colliding and therefore changes its beacon slot in the following superframes. Once the DevAddr is included again in other devices' BPOIEs, the device will keep using the same beacon slot.

Due to mobility, two groups of devices using different Beacon Period Start Time (BPST) may come into the range of each other. Their BPs may overlap with each other, resulting in beacon collision immediately, or may overlap eventually due to clock drifting. This problem is solved by merging two BPs with different BPSTs into one as follows.

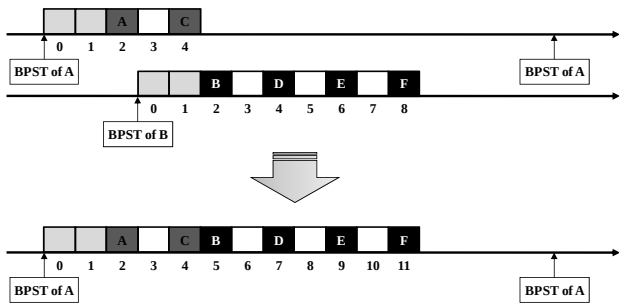


Fig. 4 Merger of overlapping BPs

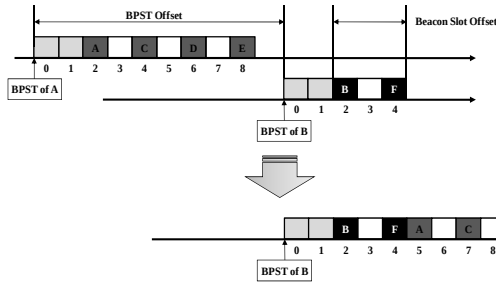


Fig. 5 Merger of non-overlapping BPs

If a device receives a beacon frame from outside of its beacon group (called an alien beacon) for multiple superframes, the device adjusts its own BPST to the BPST indicated by the alien beacon and relocates its beacon into a new beacon slot in the new BP. To ensure a unanimous merger of the BP, the device that receives an alien beacon with a BPST falling within the first half of the device's superframe should initiate the process of merging the BP first. The device may include the merging information in the BP switch IE so that the devices in the same beacon group can initiate the process in a coordinated manner, even though they do not receive the alien beacons. An example is shown in Fig. 4 and Fig. 5.

III. PROPOSED SCHEME

In this section, we propose a merger mechanism to reduce beacon period length after merger, when two or more networks with different BPST try to merger. There are several problems if the networks try to merge by original method.

First, the original method for merger is very inefficient because a merged network can have the long length of beacon period and need the contraction process of beacon period when movable devices selects beacon slot from up to mBPExtenction beacon slots located after the highest occupied beacon slot of a fixed network. Second, they meet deadlock situation when one or more networks decide to move themselves simultaneously because they don't have any criterion about which of networks to move. Moreover it is possible to move a stabilized network which exits for long superframes and has the relatively short beacon period as compared with a long lifetime. It takes long time to merge

together and to stabilize a merged network if a certain network which has the long length of beacon period or many reserved MASs for data moves.

Therefore we propose a specific criterion about selecting a movable network or a fixed network and interleaving method by choosing beacon slots from the smallest unoccupied beacon slot to the number of beacon slot required by merger. We intend to reduce the length of beacon period in merged network and total merging time.

Our proposed merger mechanism is made up of 2 phases. The first phase is that devices of each network check their own length of beacon period, current superframe number, and their own number of reserved MASs to transmit data when of networks to move. The length of beacon period which is called N_{BL} has an effect on merging time and beacon period after merger, Current superframe number, N_{SN} , has an influence on the process for stability in merging network. The number of reserved MASs, called N_{RN} , affects devices which in a merged network have to do a new negotiation for data transmission. These respective parameters with weight set to the following equation (1).

$$\overline{W} = \alpha \times N_{BL} + \beta \times N_{SN} + \gamma \times N_{RN} \quad (1)$$

where $\alpha + \beta + \gamma = 1$,

N_{BL} = Number of the last occupied slot
in beacon period,

N_{SN} = Superframe Number,

and N_{RN} = Reserved MASs Number

The second phase, the MOVE_GROUP uses precognitive information about the STAY_GROUP's beacon slots and look for available beacon slots in sequence as shown Fig. 6 from the smallest-numbered unoccupied beacon slots to the number of beacon slot required by merger.

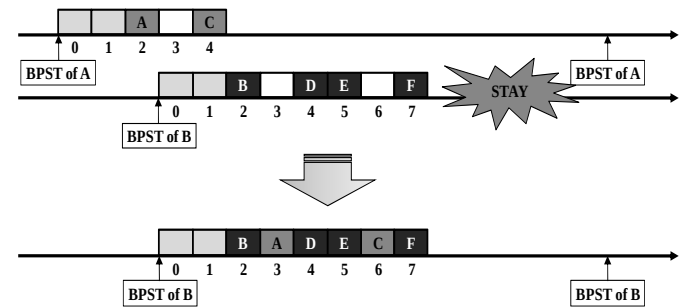


Fig. 6 Proposed merger method

If we apply our mechanism to merging networks, a merged network has not to additional contraction process to reduce the beacon period.

The environment for devices to transmit data is also formed quickly by our mechanism because of the selected

MOVE_GROUP has much less device number, reserved MASS, and stability degree than the STAY_GROUP.

IV. EVALUATION BY A SIMULATION

We assume that the total number of devices in a merged network is restricted less than 20 although a network can accept devices up to maximum 94 devices. It is impossible to merge together when one or more networks have more 20 devices. Because a merged network certainly exceeds in MaxBeaconPeriodLength according to merger mechanism.

The maximum number of beacon slots in beacon period is 86 except for signaling slot and extension slot. The signaling slot consists of 2 beacon slots and the extension slot has 8 beacon slots. Both of them can be used to process a device association procedure. Fig. 7 represents a network topology for our simulation.

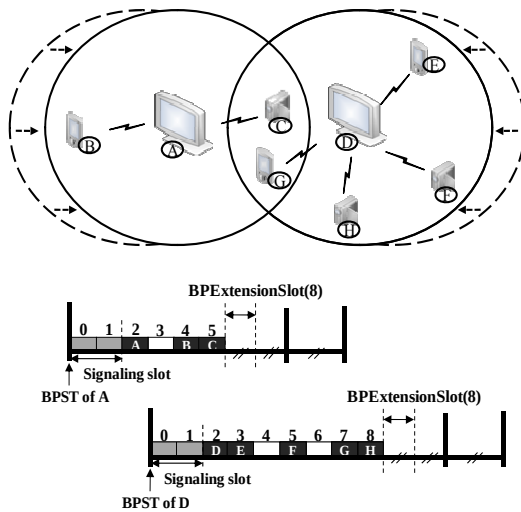


Fig. 7 Topology for our simulation

Generally, there can be empty beacon slots in beacon period of networks when two or more networks meet together. Because a lot of devices may join and leave aperiodically in a network since a network was formed by a device. The environment of our simulation can have already mentioned situation as above. However, we assume that new device can't be joining and leave until merger completion if network decide to merge together. Table 1 shows the parameters of our simulation.

Table 1. Simulation parameters

Parameters	Value
Superframe length	65.536 ms
Device number	Minimum : 2 Maximum : 20
BP Extention	8 beacon slots
MaxBeaconPeriodLength	96 beacon slots
SignalslotCount	2 beacon slots

To evaluate our scheme, we performed computer simulations. Every result has the average value about the result of 50000 experiments. Each experiment uses a randomly generated different topology.

In this paper, our final goal is to achieve that a merged network has smaller beacon period length and shorter merging time because the networks adapted our scheme to merge together. One of the important parts in our scheme is to set up for respective parameters with weight. The value of alpha and beta effects highly the beacon period length and merging time in a merged network. So they need larger weight value than it of gamma. Therefore, we set up for these parameters as follow. ($\alpha=0.4, \beta=0.4, \gamma=0.2$)

Fig. 8 represents the average beacon period length in a merged network according to the whole number of devices in the network after a merger process.

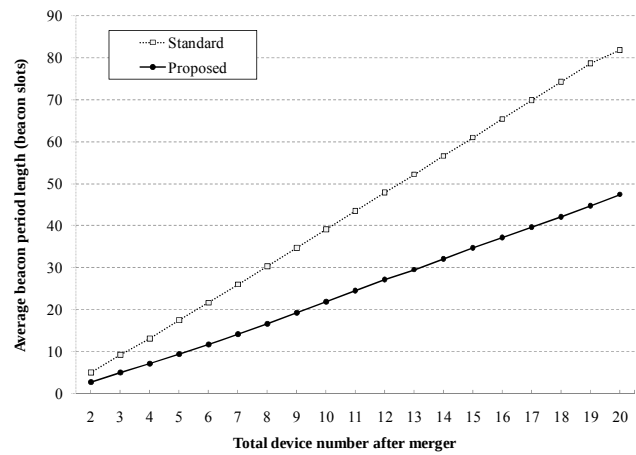


Fig. 8 Average beacon period length after merger

The result in Fig. 8 compares our merger mechanism with WiMedia MAC standard. It clearly shows that our scheme has shorter average beacon period length than WiMedia MAC standard. The more the number of devices in a merged network is, the better the performance of our scheme is.

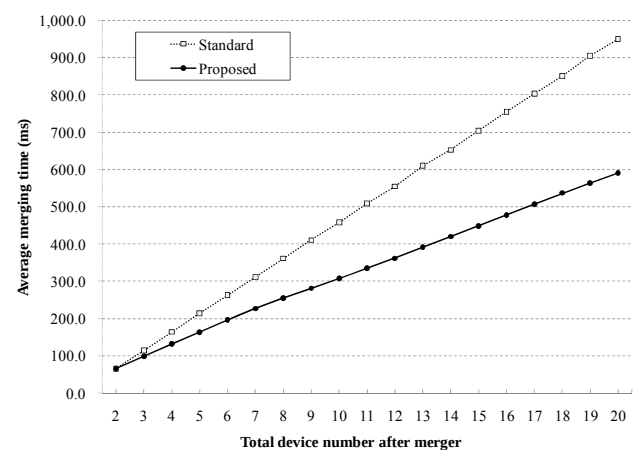


Fig. 9 Average merging time

Fig. 9 represents the average merging time related with the whole devices number in a merged network. It shows that the alpha value of the proposed scheme sets to move a network which has smaller number of devices than the others.

Accordingly, a network which selected by our scheme has faster merging time than WiMedia MAC standard. We have proved that each network related with merger decided by itself whether it is STAY_GROUP or MOVE_GROUP because of the proposed merger mechanism. A merged network doesn't need an additional contraction process so that it accomplishes faster in term of network stability than WiMedia MAC standard.

V. CONCLUSION

The WiMedia MAC is formed completely distributed network. Devices exchange beacon frames for data communication, to recognize each other. Due to network mobility, the WiMedia MAC protocol allows network merging procedure.

In this paper, we have proposed an efficient merger mechanism to reduce the beacon period length and the merging time after two or more networks with different BPST try to merge in WiMedia MAC protocol. According to our scheme, each network related with merger decided by itself whether or not it moves because of the proposed merger mechanism.

Simulation results show that our scheme offers a better performance than the WiMedia MAC protocol in terms of average beacon period length and merging time.

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