TITLE OF THE INVENTION

Method for Leader Beacon Group Selection during Beacon Group Merging in decentralized Wireless Networks

FIELD OF THE ART

The present invention relates to wireless networks and, more particularly, to apparatus and method for Leader Beacon Group selection during Beacon Group Merging.

BACKGROUND ART

In view of numerous shortfalls of the Wireless Personal Area Network (WPAN) MAC protocol of the IEEE standard 802.15.3, which is based on a centralized-control protocol, the Multi-Band OFDM Alliance (MBOA) group started its MBOA MAC subgroup. To provide avoid the short-falls of the IEEE 802.15.3 MAC, the MBOA MAC is based on a distributed protocol rather than a centralized-controlled one. In order for every device to be able to form a network by itself, each device is required to beacon in a distributed fashion. The MBOA MAC v0.6 defines the superframe of a device to be of 65536 μs. The superframe is to be composed of 256 Media Access Slots (MAS) where each MAS length is 256 μs.

The first part of a superframe is reserved for beacon transmission. The number of MAS that is actually used for beaconing is defined as Beacon Period (BP) and it can take up to 20 MAS. Within each MAS in the BP, it is sub-divided into 3 Beacon Slots (BSs). The rest of the MAS in the superframe is used for data transfer, employing either a prioritized contention-based method called Prioritized Channel Access (PCA) or a data reservation method called Distributed Reservation Protocol (DRP). The superframe of MBOA MAC is illustrated in Figure 1.

The BP is dynamic in length and consists of a dynamic number of beacon slots, which extend across up to 20 contiguous MAS. The BP expands when new devices join the Beacon Group (BG) and contracts when devices leave the BG. A BG is defined as a group of devices which synchronizes their beacon transmission within the same group of MAS and which identify these MAS as their BP. The dynamic BP of MBOA MAC is shown in Figure 2.

When two or more BGs come into range, devices are required to coalesce to a single BP, combining into a single BG. The BP of one of the BG will be expanded to accommodate beacons of other joining devices from other BGs.

Reference:

MBOA MAC v0.6 Draft Specifications

PROBLEMS TO BE SOLVED

In the prior art MAC protocol as described above, when more than one BGs come into range, they are required to coalesce into a single BG. Currently in the MBOA MAC v0.6 draft specification, there is no method defined to select which BG's BP should remain unchanged and which BG should join the unchanged BG.

Devices in BG that is required to coalesce into other BG have to change their BS, as well as reschedule their contention-based data transfer and re-negotiate their DRP reservations, if any. This is shown in Figure 3. This means that for best performance, no device would voluntarily choose to be the one to merge. Therefore, a set of rule needs to be defined to that every device can based on to decide during BG merging whether it should continue beaconing in the current BG or join another BG. In this patent, when two or more BGs merges the BG that do not need to join other BG is defined as Leader BG (LBG). The rest of the BG(s) that are required to coalesce into the LBG are defined as Follower BG (FBG). The problem to be solved here is hence to enable every device to be able to determine whether its BG is the LBG or FBG when it comes into range of one or more other BG(s).

The difficulty in defining a LBG selection method lies in how to ensure fairness. To be fair the selection method must ensure that the selection incurs the least network disruption. The term "least network disruption" itself, may be defined differently depending on implementer's requirements. One way to look at least network disruption is from the angle of least impact on existing network topology. A selection method that is based on this can be defined such that smaller BG always joins bigger BG. During BG merging, the BG with the most number of member devices will assume the LBG and the rest being FBG will coalesce into the LBG. There are two main problems in this selection method. The first problem is that BG size is a temporary value which is subjected to unpredictable changes in every superframe as devices can enter or leave anything in a WPAN. The second problem is that the total number of devices in BG is usually not propagated through the entire BG. This is especially so for MBOA MAC v0.6 draft where devices can only see devices that are up to 2 hops.

The other way to look at least network disruption is from the angle of least impact on ongoing data transfer. In the case of MBOA MAC, this means that BG with lesser existing DRP reservations joins BG with more existing DRP reservations. There are two main problems in this selection method as well. The first problem is that DRP reservation count is even more temporary than BG size, even when BG size remains unchanged. The second problem is that total DRP reservation count is usually not propagated throughout the BG and in fact, there is no sense to do that.

To avoid inconsistency of local/neighboring selection criteria that are based on temporary values (e.g. local or BG device count, local DRP count etc.), globally

consistent selection criteria can be used. One of which is network time, which is the running clock value in every device. One example of such usage is in the IEEE 802.11 TSF. The rationale of using network time is that logically, devices that are already in operation for a very long time should be subjected to less changes since they are also more likely to have stabilized already. Although LBG selected through network time may consistence and relatively fair, the downside is that high accuracy clock are required to ensure all devices in the same BG report the same network time in every superframe.

Another globally consistent selection criteria that can have been considered is the usage of MAC address of Device ID (DEVID), which it has the advantage of being very consistent as well as being fixed throughout network operation. However the disadvantage is that this method is consistently unfair to devices with less advantageous MAC address or DEVID.

As came be seen from the problems associated in various selection criteria, a consistent LBG selection method that also provide for least network disruption thus still remain a problem to be tackled, especially in the MBOA MAC v0.6 draft.

MEANS FOR SOLVING THE PROBLEMS

According to one aspect of the invention, a method to select a LBG during the merging of two or more Beacon Group (BG) comprises:

A) a procedure to broadcast merging information required for LBG selection in every superframe

B) a procedure to select LBG based on the merging information

In the merging information broadcast by every device in every superframe, a combination of the local size of the BG, a flag indicating any BG extension beyond neighbor devices, and age of the BG in term of number of superframes are included. Through the age of the BG in number of superframes, globally consistent selection is made possible without the need for high accuracy clock. The local size of the BG together with an BG extension flag provide the possibility of making LBG selection based on total BG size when there are no extension BG indicated. In the case when total size of each BG can be determined (i.e. there are no extension indicated), selection of LBG using BG size take precedence. This provide for a selection method that causes least disruption to network topology.

EFFECT OF THE INVENION

The effect of the invention is that during merging of two or more BGs, the LBG can be selected using a consistent method based on both the size and age of each BG. The size of BG is used as a higher priority comparison when the total size of each BG is known. This is to reduce overhead when bigger BG coalesce with a smaller BG. When the total size of a BG is not known, the method uses the age of each BG for comparison instead. This is to reduce the chance of an older BG from reconfiguring due to a new BG coming into the neighborhood.

The invention also employs the constant broadcasting of current merging criteria information called Merge Selection Criteria (MSC) in every superframe. The MSC convey current age and the local or total size of the BG (depending on whether there are further extensions of the BG beyond neighbor devices) in every superframe. As a result, BG merge can be performed at every superframe. In addition, the invention only uses the MSC information for LBG selection and thus does not need to invoke any message exchanges. This provides a fast and automatic mechanism for MAC to select a LBG immediately for merging once a device of different BG is detected.

BEST MODE FOR CARRYING OUT THE INVENTION

First, the generic idea of the invention is explained. In every beacon frame broadcast by every device during beaconing, an additional information known as Merge Selection Criteria (MSC) is sent together as well. The MSC contains 2 sub-information, which are the Beacon Group Superframe Count (BGSC) and Local Device Count (LDC). The BGSC is defined as the number of superframes that have passed in the current BG since the start of the BG. The LDC of a device is defined as the total number of devices in the same BG, in the radio range of the local device. This is equal to the number of neighbor devices in the same BG plus 1 for itself. In addition, the LDC also indicates whether beyond the neighbor devices that it can hears, is there anymore devices that its neighbor can hears but the local devices cannot. When devices that belong to other BG(s) are detected, the local device compares the local MSC with the MSC of these devices and based on this comparison, a LBG is decided. In deciding a LBG based on the MSCs of merging devices, priority is given to selection based on the total size of BG so as to minimize the number of device needed to switch BG. However selection based on the total size of BG will only be used when the total size of all BG can be determined (that is, there are no extended BGs indicated in LDC in all merging devices). If LBG cannot be selected through BG size either due to a tie in the BG size or there are extended BG (hence unable determine the BG size), the LBG will be selected by comparing the BGSC. Any tie in the BGSC is resolved by that the earliest BP by comparing the Beacon Period Start Time (BPST). The following paragraphs explain the patent idea in greater details.

The MSC described contains the BGSC and LDC information. The BGSC indicates the number of superframes that has passed since the start of the BG. For a WPAN where devices usually have short lifespan and of high mobility, using 24 bits (3 bytes) to represent the BGSC gives a maximum age of about 12 days (based on MBOA MAC's superframe length of 65ms) is enough for typical usage scenario. Of course, the BGSC is not limited to 24 bits and it can be made longer or shorter based on specification's requirements. As for the LDC, it indicates to other devices two things. The first thing is how many devices are there its vicinity (including itself) that belongs to same BG. This includes itself and all devices whose beacon can be heard. Another thing that the LDC indicates is whether or not there are devices in the same BG that it is unable to hear but can be heard by its neighbor devices (that are in the same BG). Another way of looking at it is that it indicates whether the BG is extended beyond its neighbor devices (that are

in the same BG). Figure 4 illustrates the LDC of each device in a sample network topology. The link between 2 nodes indicates that the nodes are able to hear each other. The LDC are made up by one number and a "+" or "-" sign. The number indicates the local device population as explained above and a "+" sign indicates the presence of an extended BG beyond a node's neighbor. A "-" sign on the other hand indicates there is no extended BG beyond its neighbor node and hence the LDC count indicates the total device count for the entire BG. To indicate the LDC, 8 bits (1 byte) is used. 7 bits will be used for counting the number of devices, hence giving maximum count to be 127 devices (more than enough for MBOA MAC v0.6 where a BP can only accommodate less than 60 devices). The other 1 bit of the LDC is used to flag whether there is any extended BG beyond the neighbor devices. Although 8 bits are used here, this patent is not limited to the number of bit used. Rather, implementer can choose to use various length for LDC depending on usage scenario. Using the 24-bit BGSC and 8-bit LDC, one possible way of representing MSC is shown in Figure 5.

The procedure to propagate and broadcast MSC goes like this. When a device first starts up, it scans the wireless medium for any existing BG. If there is no BG, it starts a new BG and initializes its BGSC to 1 (indicating it is the first superframe of the BG) and its LDC to "1-" (indicating there is only 1 device in the vicinity and there is no extended BG). This MSC information is send on its very first beacon frame that it broadcasts. However, if a device scans and finds one or more BG in the vicinity, it then chooses one BG to join and adopt the BGSC broadcast in the beacon of the BG. The BGSC is incremented by 1 on every superframe. The LDC broadcast in every superframe is updated every superframe and is derived by beacon information heard in the last superframe. The LDC count is determined by the number of devices whose beacon was heard in the BP of the last superframe. In addition, from the beacon of neighbor devices heard in last superframe, it is assumed it contain information of their neighbor devices. In MBOA MAC, this information is presented in the Beacon Period Occupancy Information Element (BPOIE) in the beacon frame. From the BPOIE, if there are devices that can be heard by the neighbor devices but not by the local device, then the LDC will indicate the presence of extended BG.

Next, the LBG selection method is explained here. In situations when devices discover that there are devices belonging to other BG presents within wireless range, these devices may choose to coalesce into a single BG. In the case of MBOA MAC v0.6, it is mandatory for devices from different BG to coalesce into a single BG when they come within radio range. To agree on one BG to coalesce to, a LBG needs to be decided in a distribute manner. This patent present a LBG selection method based on the MSC information broadcasted by every device in the manner described in the previous paragraph. First, a local device examine if there are any devices with extended BG indicated in its MSC. If there are no devices having extended BG, the LBG can be decided using the total size of the BG so that there are least disruption to a bigger BG and potentially less devices switching BG. In this case, the LBG can be decided by

comparing the device count in LDC. If there are tie in the LDC comparison, the short-listed BGs are compared based on BGSC.

If initially there are devices with extended BG, there is no way to decide LBG based on BG size since there is no way to know how many devices are there beyond these extended BG. Instead, the LBG is decided using BGSC. However, before performing BGSC comparison, trivial case when a non-extended BG reports LDC lower than that of any extended BG is discarded. After discarding the devices with non-extended BG and having smaller device count in LDC than any devices of extended BG, the remaining device will the be subjected to the BGSC comparison.

In BGSC comparison, the BG having device or devices with the highest BGSC will be becomes the LBG. If there is more than one BG having its device or devices with the highest BGSC, among these BG, the BG with the earliest BPST will be the LBG. This is illustrated in Figure 6. In Figure 6, at time t_0, 3 devices of different BGs namely, BG-1, BG-2 and BG-3 compared their BGSC and arrived at a tie. However, BG-3, having the earliest BPST ($BPST_{100}$) becomes the LBG.

Figure 7 illustrate the described LBG selection algorithm using flow chart.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the timing structure of the superframe of MBOA MAC v0.6 draft specification.

Figure 2 shows the structure of the dynamic Beacon Period of MBOA MAC v0.6 draft specification.

Figure 3 shows the impact on devices when it is required to coalesce to another Beacon Period.

Figure 4 shows the Local Device Count (LDC) values of devices in an example wireless network topology.

Figure 5 shows data structure within the Merge Selection Criteria (MSC) information.

Figure 6 illustrates how tie in Beacon Group Superframe Count (BGSC) comparison is resolved using Beacon Period Start Time (BPST) comparison.

Figure 7 illustrates the Leader Beacon Group (LBG) selection method using flow chart.

WHAT IS CLAIMED IS

1. A method to select a Leader Beacon Groups (LBG) during the merging of two or more Beacon Group (BG), comprising:

A) a procedure to broadcast merging information required for LBG selection
B) a procedure to select LBG based on broadcasted merging information

2. Said procedure to broadcast merging information required for LBG selection in claim 1, further comprises:

A) a merging information data structure called Merge Selection Criteria (MSC)
B) a procedure to update the age of the BG in every superframe
C) a procedure to update the Local Device Count (LDC) information in every superframe
D) a step to broadcast updated MSC in every superframe, preferably together with beacon frame

3. Said merging information data structure called Merge Selection Criteria (MSC) in claim 2, further comprising:

A) an age information of a BG called Beacon Group Superframe Count (BGSC)
B) a local BG size information called Local Device Count (LDC)

4. Said age information of a BG called Beacon Group Superframe Count (BGSC) in claim 3, defining the age of a BG in term of number of superframes. The BGSC can be represented between 8 to 64 bits, preferably between 16 to 32 bits.

5. Said local BG size information called Local Device Count (LDC), further comprises:

A) the number of devices belonging to the same BG that the local device is able to hear. This can be represented between 2 to 16 bits, preferably between 4 to 8 bits
B) a flag indicating whether there are extended BG beyond the neighbor devices of the local device. This can be represented between 1 to 8 bits, preferably 1 bit

6. Said procedure to update the age of the BG in every superframe in claim 2, further comprises:

A) a step to adopt the BGSC of the BG that the local device just joins or merges into
B) a step to increment BGSC after every superframe

7. Said procedure to update the Local Device Count (LDC) information in every superframe in claim 2, further comprises:

A) a step to update the number of local device if LDC to be equal to the number of device belonging to the same BG whose beacon was heard in the last superframe
B) a step to indicate the presence of extended BG in the extended BG flag of LDC if it can see from its neighbor device's beacon frame that there are devices that the local device are not able to hear.

8. Said procedure to select LBG based on broadcasted merging information in claim 1, further comprising:

A) a step to select whether to use BGSC or LDC within MSC to make comparison based on merging devices' extended BG flags in LDC.

B) a step to use BGSC to make comparison when there is a tie in LDC comparison

C) a step before making BGSC comparison, to filter away all devices that have no extended BG and have lower local device count in LDC as compared to the highest local device count found among devices with extended BG.

D) a step to select the BG with the earliest Beacon Period Start Time (BPST) as the LBG when there is a tie in BGSC comparison.