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Investigating Resource Assignment for Coexisting PANs in Ubiquitous Environment

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1 Introduction

Currently wireless connection is used by a large number of electronic devices because of its convenience. We can see such wireless devices in our home, office, and factory which can be considered as ubiquitous environment. In addition, portable devices equipped with wireless module are very popular so people always carry them with themselves all the time. As a result, communications between wireless devices forming a Personal Area Network (PAN) have become widespread nowadays, and there is high possibility that many PANs coexist in any places, especially public areas. ZigBee is hoped to be a promising wireless standard for PAN.

ZigBee Alliance has developed a ZigBee standard [2] for a Low-Rate Wireless Personal Area Network (LR-WPAN) which is a network designed for low-cost very-low-power short-range wireless communication. The ZigBee standard employs IEEE 802.15.4 as its MAC and PHY specification. Applications in fields such as industrial, agricultural, vehicular, residential, medical sensors, and actuators have more relaxed throughput requirements. Moreover, these applications require substantially lower power consumption than is currently provided in existing standard implementation. Thus, PANs using ZigBee technology will come into wide use and must coexist with others.

It is known that wireless channels are limited resource and only one device can use a channel for a specified time. In other words, two nodes cannot transmit data on the same channel at the same time. Therefore, a wireless device must be assigned an available channel together with non-overlapped access time, or it must contend for an available channel in order to have successful communication with other party. Previous literature [1] have studied time assignments which consider individual node separately. However, such solutions cannot apply to the coexistence of PANs directly because they must consider a group of nodes instead of individual node. The schedule can be assigned to all nodes in a group correctly when considering PAN, instead of individual node. Data transmission from any member in a group will not disturb nodes in other groups.

This paper proposes a resource assignment scheme to manage the coexistence of ZigBee devices. The proposal consider PAN and node separately in order to assign a right channel and time to both PAN and node.

2 Related Work

Time Division Multiple Access (TDMA) is a conventional proposal that assigns shared physical medium to each node individually. Carrier Sense Multiple Access (CSMA) is a probabilistic MAC protocol in which a node verifies the absence of other traffic before transmitting on a shared physical medium. Nodes using S-MAC [1] negotiate a schedule, i.e., when nodes are awake and asleep within a frame. These proposals are designed to assign time for any pair of sender and receiver. However, the receivers of any sender in a PAN are limited to its PAN members while a communication party in a PAN may disturb other communication parties in other PANs. Protocols can be optimized by considering a group of nodes, or PAN, instead of individual node. Our proposal assigns both channels and time to PANs which in turn determine assigned time for each node in their PANs.

3 IEEE 802.15.4 and ZigBee

There are three types of logical devices: ZigBee Coordinator (ZC), ZigBee Router (ZR), and ZigBee End Device (ZED), defined in ZigBee NWK layer. A network is started by a full function device when it becomes the PAN coordinator. All Networks must have exactly one PAN coordinator in each network.

Two different types of devices are defined in an 802.15.4 network, a full function device (FFD) and a reduced function device (RFD). A FFD can talk to RFDs and other FFDs, and operate in three modes serving either as a ZC, a ZR, or a ZED. A RFD can only talk to a FFD and is intended for extremely simple applications.

The standard supports two network topologies, star and peer-to-peer. In the star topology, communication is controlled by a PAN coordinator that operates as a network master, while devices operate as slaves and communicate only with the PAN coordinator. The devices may be either FFDs or RFDs.

4 Problem Statement

We consider the situation where multiple PANs exist in a same area (Fig. 1). Each PAN composes of few ZEDs which stays one hop from the ZC, so that a one-hop star topology is constructed in each PAN.

As an example shown in the figure, a mobile phone and a sensor node serves as a ZC and a ZED, respectively. Each sensor reports sensing information periodically to the mobile phone. Sensing information may be blood pressure, pulse, temperature, etc. required in

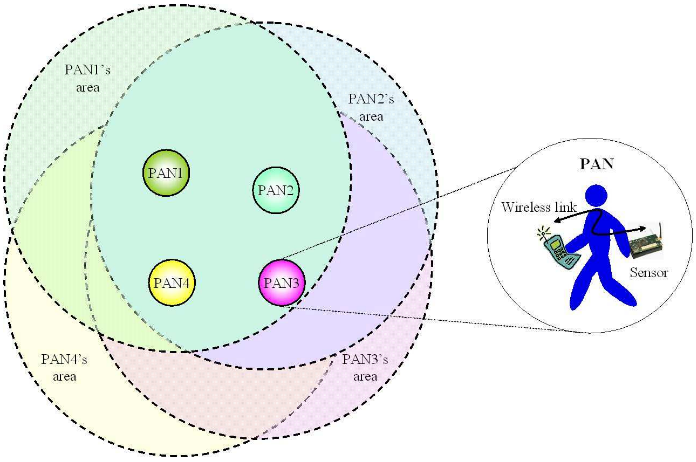

Figure 1 A dashed circle shows communication area of each PAN. A PAN stays inside other PANs' area.

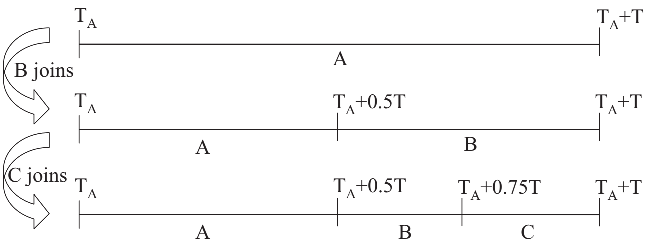

Figure 2 Three PANs coexist in a same area.

personal health care application. After receiving such information from the sensors, mobile phone forwards collected data to the health center.

Each person needs one PAN and take it with himself all the time for the above application. When they and their PAN appear in public areas (e.g., train, bus, station, park, office), the PANs using the same channel cannot communicate with their sensors. Therefore, we need a decentralize scheme to determine channel and time in order to avoid collision with others.

5 Resource Assignment Algorithm

In our proposal, available channel and time for any PAN are determined by ZC itself or assigned by the other ZC. Those channel and time are shared by every node (a ZC and ZEDs) in that PAN. ZC then assigns channel and time of its own PAN to all of its ZEDs.

ZC starts its PAN (says PAN A) by randomly choosing one channel from all available channels. It then scans the chosen channel to check whether someone are using that channel. If no one uses that channel, it decides to use that channel and determines shared *timeslot* (T). Other PANs that use the same channel will share available time from this timeslot. Therefore, ZC maintains *active period* of its PAN. Active period is a multiplication of *active ratio* (R) and timeslot, i.e., $R \times T$. Each ZC also keeps a *starting time* (S) of its active period. As a result, the parameters of PAN A are: $R_A = 1$ and $S_A = T_A$.

If ZC (says ZC from PAN B) finds that some PAN (PAN A) is using the chosen channel, it will request time from that PAN. When a PAN receives a request, it gives the latter half of its active period to the requester if possible. If its active period is shorter than a threshold, it will refuse any request. After getting the time, the parameters of PAN A and B are: $R_A = 1/2$, $S_A = T_A$, $R_B = 1/2$, $S_B = T_A + T/2$. Not only its own R and S, but each ZC also needs to maintain R and S of the following PANs: (1) the PAN whose active period follows its active period, (2) the PAN whose active period starts from the beginning of shared timeslot. Every ZC periodically broadcasts R, S, and other information by using beacon message. Let the format of management table be "own PAN: other PANs". Current management table of PAN A and B are "A*:B" and "B:A*", respectively. Asterisk is used to specify the PAN whose active period starts from the beginning of shared timeslot.

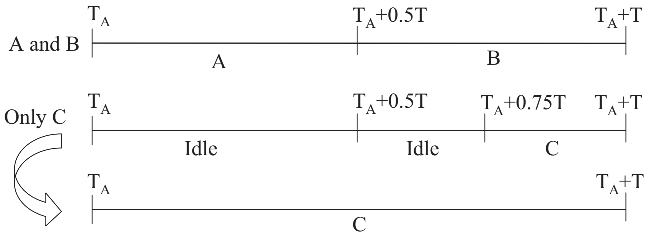

Figure 3 Because PAN C left, PAN A coexists with PAN B while PAN C stays alone.

If PAN C joins the current network and gets time from PAN B, the parameters will be: $R_A = 1/2$, $S_A = T_A$, $R_B = 1/4$, $S_B = T_A + T/2$, $R_C = 1/4$, $S_C = T_A + 3T/4$. The management table is updated to "A*:B", "B:A*, C", and "C:ϕ". Coexistence of PAN A, B, and C are illustrated in Fig 2. Each ZC updates its starting time by adding T every timeslot.

When any PAN in management table leaves, the PAN who manages that table will take left PAN's time and merge with its time. If PAN C leaves, only R_B changes to 1/2, and only B's table is updated to "B:A*". Because a ZC always listens to beacon message from others, it will extend its active period if possible. For example, when PAN C leaves, it does not listen to beacon messages from A and B anymore. It will extend its active period to full timeslot because no one uses the same channel. After knowing active period, ZC assigns time equally to each ZED in its PAN.

6 Conclusion

This paper has proposed a resource assignment algorithm for coexisting ZigBee devices. ZigBee nodes only need to communicate with others in its PAN. Therefore, the proposed protocol assigns both channels and time by distinguish PAN and node.

References

[1] W. Ye, J. S. Heidemann, and D. Estrin. An energy-efficient mac protocol for wireless sensor networks. In *Proceedings of INFOCOM*, June 2002.

[2] ZigBee Specification, ZigBee Alliance, Dec. 2006.