ADAPTIVE TIME ALLOCATION FOR AN ENVIRONMENT WHERE THE NEXT GENERATION OF LOW AND HIGH DATA RATE WIRELESS PAN COEXIST

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ABSTRACT

In an environment where the next generations of low and high rate Wireless Personal Area Networks (WPAN) coexist, an Adaptive Slot Allocation approach is proposed in order to improve the network performance. In this paper, the coexistence is achieved by applying the Common Signaling Mode in the coordinators of the network, and the Cognitive Radio concept in the main piconet coordinator. As a result, the main piconet coordinator can be understood by the other coordinators and it is also able to monitor the network traffic. The proposed approach is evaluated by computer simulation and compared to the fixed slot allocation.

1. INTRODUCTION

Next generation of Wireless Personal Area Networks (WPAN) are defined by two alternative standards, IEEE 802.15.3a and IEEE 802.15.4a, which correspond to high rate and low rate physical layer, respectively. They will be based on Ultra Wide Band (UWB) technology and will utilize the same frequency spectrum. Moreover, for the high data rate WPAN it is expected to have two sorts of systems with different physical layers. One based on DS-UWB [1] and the other one based on Multi-band OFDM (MB-OFDM) [2]. Therefore, interference between these systems may occur. In order to allow these systems to operate in the same environment, in this paper we assume that coexistence between them is achieved through the use of a Common Signaling Mode (CSM) [3], which is a method that allow different physical technologies to communicate with each other, by the coordinators of the network. In our network, there are four coordinators, one for each wireless network system (DS-UWB, MB-OFDM and Low rate WPAN (LR-WPAN)) and one called the main piconet coordinator, which has the Cognitive Radio capability to monitor the traffic of the network. Through the use of CSM the main piconet coordinator's beacon can be understood by the other coordinators, and then, it can inform them about the allowed time duration where each system can transmit. The advantage of our assumed network is that the three systems can coexist at the expense of increased complexity on only four devices, the coordinators. Therefore, it is employed a centralized TDMA, as defined in the standard of IEEE 802.15.3 [4], where the main piconet coordinator assigns a time duration to each network system. Once the coordinators of each system are aware of their assigned time, they will manage their devices in order to allow them to transmit only during the allowed time. By applying the Cognitive Radio concept in the main piconet coordinator, since this sort of radio can learn the environment changes and adapt to it [5], it is able to monitor the traffic of each system and then, adaptively assign their time duration in order to maximize the throughput and satisfy the quality of service of each system, instead of dividing the total amount of time equally. Fixing the assigned time equally for each system is the easiest way to define the time duration where each system can transmit. However, doing that, the efficiency of the network is low, since the needs and the characteristics of each network differ from each other. In this paper, an approach to define the amount of slots that each system can transmit based on the monitored traffic is proposed.

This paper is organized as follows. The network model assumed in this paper is presented in Section 2. The algorithm for the adaptive slot allocation is described in Section 3. Simulation performance evaluation, comparing the throughput of each system when the proposed method of adaptive time allocation is applied to the case when the assigned time allocation is fixed, is presented in Section 4. Finally, concluding remarks are given in Section 5.

2. NETWORK MODEL

The network model assumed in this paper is shown in Fig. 1. In this network, the DS-UWB, MB-OFDM and LR-WPAN devices coexist. The coexistence is achieved by applying the CSM technology, which is a method that allows different wireless technologies and devices to communicate with each other, in the coordinators of the network, and then, the main piconet coordinator can be understood by other system coordinators. Moreover, we assume the main coordinator possesses Cognitive Radio technology and can monitor the traffic of the network. The network topology is a clustered star topology.

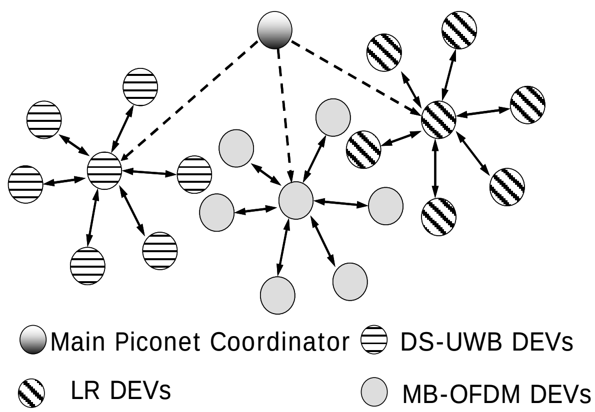

Fig. 1. Network Model

The superframe structure of our assumed network is shown in Fig. 2. As it can be seen the beacon of the main piconet coordinator is followed by the other systems beacons, and then, the devices are able to transmit.

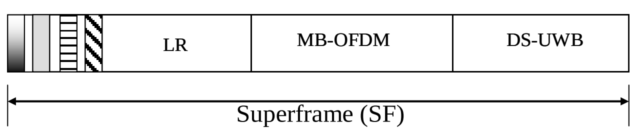

Fig. 2. Superframe Structure

3. ADAPTIVE SLOT ALLOCATION ALGORITHM

In the following the adaptive slot allocation algorithm applied by the main piconet coordinator, when the Low and High Rate WPAN coexist, is described.

1. At the beginning, the main coordinator assigns the same amount of slots to each system.
2. Each coordinator of each system will manage their devices, in order to allow them to transmit only during the assigned time.
3. The main coordinator monitors the network traffic, and based on the traffic volume information the new number of slots for each system are calculated as:

$$\alpha = \frac{Traffic\_DS}{Traffic\_MB} \tag{1}$$

$$\beta = \frac{w \cdot Traffic\_LR}{Traffic\_DS} \tag{2}$$

$$\gamma = \frac{Traffic\_MB}{w \cdot Traffic\_LR} \tag{3}$$

$$Nslots\_DS = \left\lceil \frac{Nslots}{(1+\beta+\beta\gamma)} \right\rceil \tag{4}$$

$$Nslots\_MB = \left\lceil \frac{NSlots\_DS}{\alpha} \right\rceil \tag{5}$$

$$Nslots\_LR = Nslots - Nslots\_DS - Nslots\_MB \tag{6}$$

where Traffic_DS, Traffic_MB and Traffic_LR are the DS-UWB, MB-OFDM and LR-WPAN systems traffic volume, respectively. w is a weight applied to compensate the difference in the data rate of LR-WPAN to High Rate WPAN. Finally, Nslots are the total amount of slots in a superframe, and Nslots_DS, Nslots_MB and Nslots_LR are the amount of slots for each system.

Fig. 3 shows schematically the algorithm.

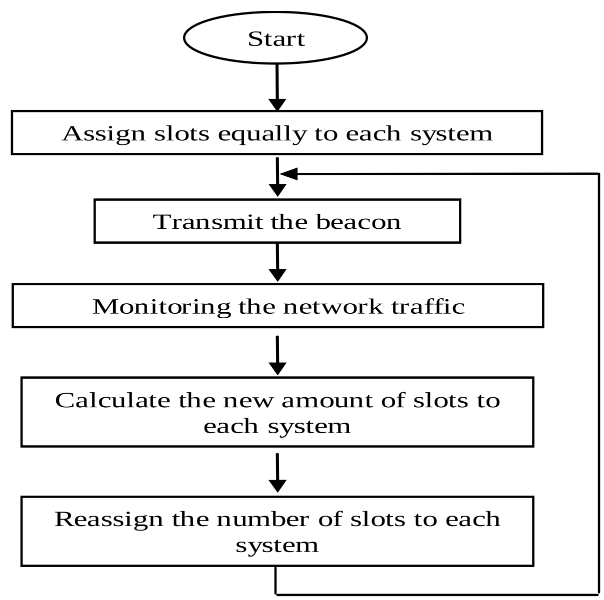

Fig. 3. Adaptive Slot Allocation Algorithm

4. SIMULATION RESULTS

The adaptive slot allocation approach is evaluated and compared to the case when the slot allocation is fixed by computer simulations. In this paper, the error in the CSM and the cognitive radio are not considered. Moreover, it is assumed that collisions not occur and during one slot, only one packet of High Rate WPAN can be transmitted. Therefore, due to the low data rate of the LR-WPAN system, its devices need more than one slot in order to transmit one packet.

In this paper, the traffic is generated by using an on-off source model following the Pareto distribution as defined in [6]. The parameters adopted in the simulation are as follows:

Table 1. Network Parameters

Number of DS-UWB devices	4
Number of MB-OFDM devices	2
Number of LR-WPAN devices	2
Superframe Duration	16 ms
Number of Superframes	5*10^4

Table 2. High Rate WPAN Parameters

Data Rate	100 Mbps	SIFS	5 µs
Preamble	5 µs	DIFS	10 µs
PHY Header	5 µs	Payload	1500 bytes
MAC Header	5 µs	ACK	1 µs

Table 3. LR-WPAN Parameters

Data Rate	1 Mbps	SIFS	16 µs
Preamble	32 µs	DIFS	34 µs
PHY Header	8 µs	Payload	500 bits
MAC Header	64 bits	ACK size	32 bits

The proposed method was evaluated in terms of packet drop ratio and throughput.

Fig. 4 shows the Total Packet Drop Ratio of the network and the Total Throughput of the network is shown in Fig. 5. Simulation results show that the performance of the adaptive slot allocation outperforms the fixed approach. A higher throughput and lower packet drop ratio were obtained by applying the adaptive slot allocation approach.

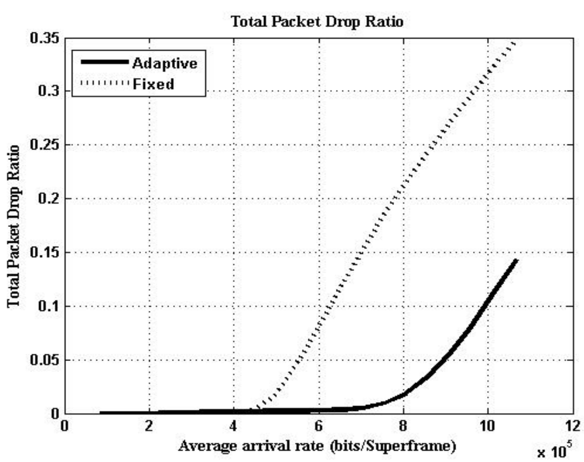

Fig. 4. Total Packet Drop Ratio

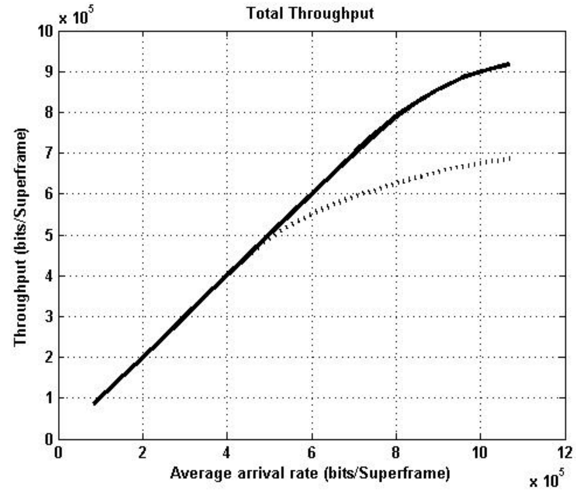

Fig. 5. Total Throughput

5. CONCLUSIONS

In this paper, an adaptive slot allocation approach was proposed to be applied in a environment where the next generation of low and high rate WPAN coexist. The proposed approach was evaluated by computer simulations, and the results showed that by applying the proposed approach a higher performance could be achieved, that is, it yields a higher throughput and a lower packet drop ratio than a fixed slot allocation.

For future works, we have to take into account the error in the CSM and cognitive radio in order to obtain a more realistic result.

6. REFERENCES

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