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Scalable Performance Enhancement in Coexistent Heterogeneous Wireless Packet Networks

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Abstract **- In today's scenario as the usage of ISM band is increasing rapidly there are many scenarios where we need communication systems like wireless local area networks (WLANs) based on IEEE 802.11b specifications and wireless personal area networks (WPANs) based on IEEE 802.15.4 specifications coexisting in the same place. In case of such coexistent heterogeneous networks we have performance degradation. In this paper, we propose a new scheme using channel scheduling for enhancing the performance of the networks. To evaluate the effectiveness of the proposed scheme, the performance metrics such as throughput, average end-end delay and average jitter is measured using Qualnet 4.5 simulation software. The simulation results show that the proposed scheme is effective in performance improvement for coexistence network of IEEE 802.15.4 for various topologies.**

***Keywords*– Coexistence, Heterogeneous wireless network, IEEE 802.15.4, IEEE 802.11b.**

I. INTRODUCTION

The Industrial, Scientific and Medical (ISM) band is widely used among popular wireless network standards such as IEEE 802.15.4 Low-Rate Wireless Personal Area Network (LRWPAN), IEEE 802.11b Wireless Local Area Network (WLAN), IEEE 802.15.3, and Bluetooth. Because of the mobility and ubiquitous deployment of wireless systems, there are many scenarios where different systems operate in the same place at the same time.

The term coexistence is defined as "the ability of one system to perform a task in a given shared environment where other systems may or may not be using the same set of rules". For example, if 802.15.4 sensor network system is to be deployed in the hospital building for emergency medical care, a main design issue will be providing the coexistence of 802.15.4 and other wireless systems. In case the other system causes radio channel interference, the sensor network system cannot continue the normal operation and may lose critical information such as emergency patient vital signals and emergency patient information.

IEEE 802.15.4 is for low data rate wireless connectivity with fixed, portable, and moving devices with no battery or very limited battery consumption requirements typically operating in the personal operating space (POS) of 10 m, ultra-low complexity and ultra-low cost. To achieve low power consumption, IEEE 802.15.4 assumes that the amount of data transmitted is short and also infrequently in order to keep a low duty cycle.

Examples of practical wireless sensor network systems are wild life habitat monitoring, hospital emergency medical care and health monitoring, forest fire detection and tracking, traffic monitoring and others. Its operational frequency band includes the 2.4GHz Industrial, scientific and medical band providing worldwide availability. IEEE 802.11b is a standard satisfying the needs of wireless personal area networks. This standard is characterized by maintaining a high level of simplicity, allowing for low cost and low power implementations.

It is interesting to note that the effect caused by radio interference is not reciprocal when multiple wireless systems operate simultaneously. It is because of the difference in radio transmission range. 802.11b uses a longer range radio than 802.15.4 system. 802.11b WLAN has radio range of 100 m and 802.15.4 LR-PAN has radio range of 10m. Thus, 802.11b can give radio interference to 802.15.4 system in a large area and from a long distance. Therefore, large-scale 802.15.4 based sensor network system is vulnerable to the interference from 802.11b. Moreover, 802.11b systems are employed in many portable devices including hand-held Personal Data Assistant (PDA) and laptop computers.

In the coexistence of IEEE 802.15.4 and IEEE 802.11b, the main concern is the performance degradation of IEEE 802.1.5.4 caused by the interference of IEEE 802.11b. A measurement study reported that over 92 % of the 802.15.4 frames were lost by the interference of IEEE 802.11b. In general we have to consider the multiple WPAN nodes when multiple sensor nodes are used, where time slot mechanism is not helpful in WPAN network because ZigBee is a mesh networking technology. To overcome both the disadvantages above mentioned in this paper, we propose a scheme using channel scheduling to solve the performance degradation of IEEE 802.15.4. Especially, the proposed scheme is intended to support coexistence performance issue for IEEE 802.15.4 multi-hop network. The rest of this paper is organized as follows: Section 2 summarizes the related works. The proposed scheme is presented in Section 3. Simulation results are discussed in Section 4. Finally, we conclude our paper.

II. RELATED WORK

Figure 1 shows the operational frequency spectrum of both IEEE 802.15.4(ZigBee) and IEEE 802.11b (WLAN) networks. A WLAN system has eleven channels. Each channel occupies 22 MHz and up to 3 separate channels can be simultaneously used without any mutual interference. Channels 1, 6, and 11 can be used for neighboring IEEE 802.11 WLAN Access Points (APs), as shown in Figure 1, to mitigate the interference. On the other hand, ZigBee networks have sixteen channels in 2.4 GHz band which can be used simultaneously without any mutual interference among them. Since the transmission power of WLAN is usually 100 times larger than that of ZigBee networks, we focus on the effect of interference from WLAN to ZigBee and the interference among WLAN nodes because of collisions caused by the multiple transmissions in case of heterogeneous wireless packet network

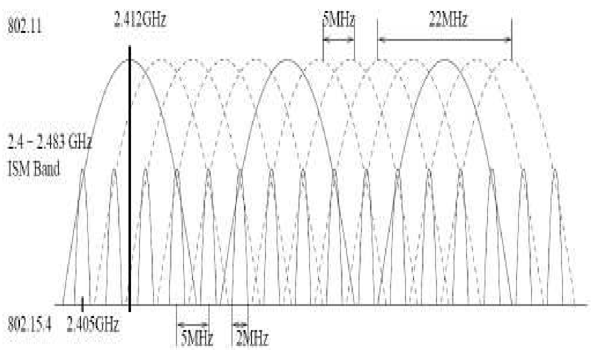


Fig1: Frequency Spectrum of IEEE 802.11b and 802.15.4 in the 2.4GHz ISM band.

In IEEE 802.15.4 standard, a transmission between PAN coordinator and devices is performed inside the 2.4 GHz ISM band, at 250 kbps, and exploiting one of the 16 available channels. As shown in table I, such channels have a 3 MHz bandwidth and are uniformly distributed within the ISM band.

Table I: 2.4GHz ISM BAND, IEEE 802.15.4 and IEEE 802.11 CHANNELS.

	IEEE 802.11b		IEEE 802.15.4	
	channel	Frequency (GHZ)	channel	Frequency (GHZ)
2.4 GHZ ISM Band	1	2.401-2.423	1	2.405
	2	2.404-2.426	2	2.410
	3	2.411-2.433	3	2.415
	4	2.416-2.438	4	2.420
	5	2.421-2.443	5	2.425
	6	2.426-2.448	6	2.430
	7	2.431-2.453	7	2.435
	8	2.436-2.458	8	2.440
	9	2.441-2.463	9	2.445
	10	2.446-2.468	10	2.450
	11	2.451-2.473	11	2.455
			12	2.460
			13	2.465
			14	2.470
			15	2.475
			16	2.480

Some related researches study the packet transmission management scheme for mitigating the interference effects in WPAN is described in [5]. In [6], characteristics of different classes of routing protocols are described. In [7], Probability analysis of channel collision between IEEE 802.11b and IEEE 802.15.4 has been described. In [8], Inter packet delay for the coexistence of IEEE 802.15.4 and IEEE 802.11b is analyzed. In [9], Modelling of Channel Conflict Probabilities and interference analysis of coexistent heterogeneous wireless packet networks is described. In [10], technical introduction of the IEEE 802.15.4 standard and analyzes the coexistent impact of an IEEE 802.15.4 network on the IEEE 802.11b devices is analyzed. In [11], Performance evaluation of IEEE 802.15.4 for medical applications is analyzed. In [12], Packet Error Rate analysis of IEEE 802.15.4 under IEEE 802.11b interference is analyzed. To the best knowledge of the authors, performance analysis of coexistence heterogeneous network for random and grid topology for static and mobility case by channel scheduling scheme has not been discussed in the literature.

III PROPOSED SCHEME

In this paper, we propose a channel scheduling scheme based analysis for the performance metrics such as throughput, average end-end delay and average jitter of IEEE 802.15.4. We consider a heterogeneous network with random and grid topology. The performance of IEEE 802.15.4 under the interference of IEEE 802.11b and also among WLAN nodes is analyzed using Qualnet 4.5 simulation. For simulation, the slotted CSMA/CA of the IEEE 802.15.4 model is developed using Qualnet 4.5 simulator. The scenario of coexistence heterogeneous network for random and grid topology is shown in figure 2(a-b).

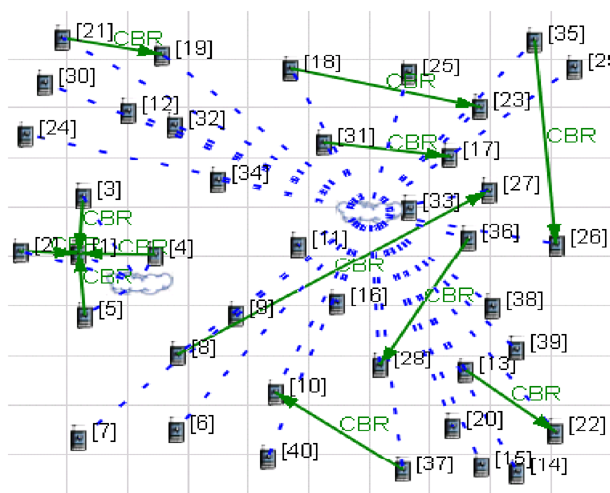


Fig: 2.a Coexistence Heterogeneous network Scenario for Random Topology

The figure 2.a shows the scenario of Coexistence Heterogeneous network for Random Topology developed in Qualnet 4.5 simulator. In this scenario 5 WPAN nodes numbered as 1,2,3,4 and 5 in the above figure and 35 WLAN nodes numbered from 6 to 40 are used. All the nodes are placed randomly except WPAN nodes. From 40 nodes only 25% nodes are assumed as transmitting nodes. In this scenario the node 1 is FFD (Fully Functional Device) and node 2, 3, 4 and 5 are RFD (Reduced Functional Device). For this topology seed value is taken as 5.

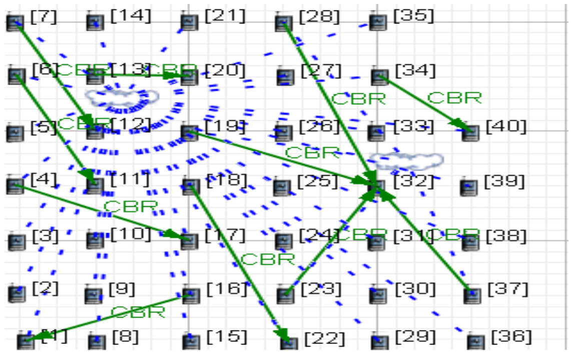


Fig: 2.b Coexistence Heterogeneous network Scenario for Grid Topology

The figure 2.b shows the scenario of Coexistence Heterogeneous network for Grid Topology developed in Qualnet 4.5 simulator. In this scenario 5 WPAN nodes numbered as 19,23,28,32 and 37 in the above figure and 35 WLAN nodes are used. All the nodes are placed at equal distance from another. From 40 nodes only 25% nodes are assumed as transmitting nodes. In this scenario the node32 is FFD (Fully Functional Device) and node 19, 23, 28 and 37 are RFD (Reduced Functional Device).

In this scheme, the nodes are separated based on the type of network and each network is allocated a unique channel frequency for error free transmission and specific channel time slot is allocated between the nodes for packet transmission in case of random and grid topologies.

IV.SIMULATION RESULTS AND DISCUSSION

To evaluate the effectiveness of the proposed scheme in a coexistence heterogeneous wireless network, a simulation study was conducted using Qualnet 4.5 simulator. The simulation configuration and parameters used in this paper is shown in Table II

Table II: Simulation Configuration and Parameters

Parameter	IEEE 802.11b	IEEE 802.15.4
Number of Nodes	35	5
Transmission Power	15dbm	3dbm
Modulation	CCK	OQPSK
MAC Protocol	802.11	802.15.4
Routing Protocol	Bellman ford	AODV
No of Packets	100	100
Payload Size	1500bytes	105bytes
Simulation Time	35s	35s
Packet Interval	100ms	1ms
Packet Transmission Time	5s	1ms
Test bed size	40m*40m	40m*40m

To study the impact of coexistence on the performance of the 802.15.4 network, measurements were made in an experimental environment as shown in Fig. 2(a-b). In all mentioned topologies 25% nodes are transmitting nodes. The effectiveness of the proposed scheme was measured with three different metrics such as Throughput, Average End-End delay and Average jitter. The figure 3(a-f) shows the performance of 802.15.4 network for the three different metrics by utilizing the scheme for static model.

Figure 3.a shows the throughput for random topology. After implementation of the scheme the throughput has been increased. Here in the graph we can see the analysis with and without implementation of scheme for static model. The collision free transmission results in higher throughput for WLAN and WPAN nodes. After implementation of the scheme throughput is increased by 16.8%.

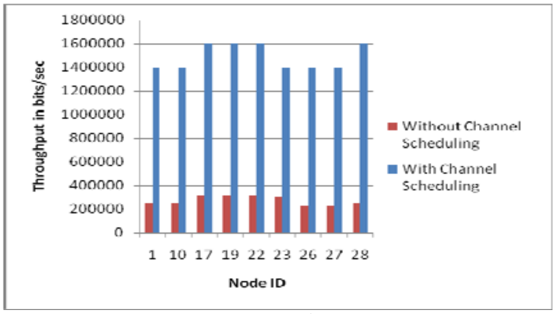


Fig: 3.a Throughput analysis for Random Topology

Figure 3.b shows the average end-end delay for random topology. After implementation of the scheme the average end-end delay has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for static model. After implementation of the scheme average end-end delay is decreased by 3%.

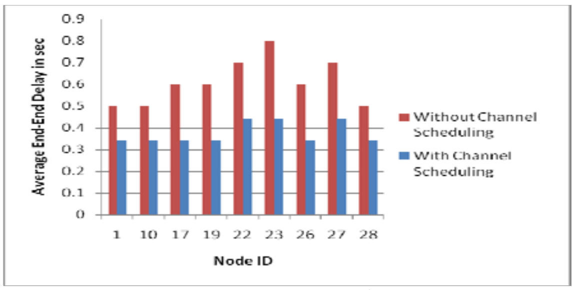


Fig: 3.b Average End-End delay analysis for Random Topology

Figure 3.c shows the average jitter for random topology. After implementation of the scheme the average jitter has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for static model. After implementation of the scheme Average Jitter is decreased by 5%.

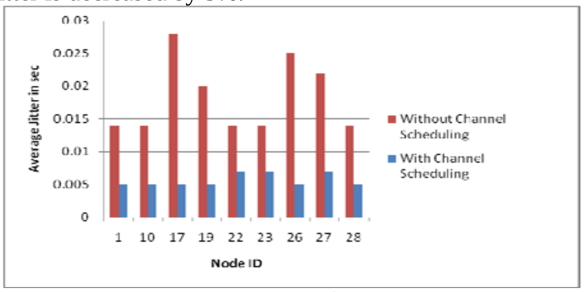


Fig: 3.c Average Jitter analysis for Random Topology

Figure 3(d-f) shows the performance analysis of 802.15.4 network and other WLAN nodes for grid topology. The grid topology scenario is shown in figure 2.b.

In grid topology nodes 19, 23, 28 and 37 are end device and node 32 is PAN coordinator respectively. Rest of the nodes is WLAN nodes.

Figure 3.d shows the throughput for grid Topology. After implementation of the scheme the throughput has been increased. Here in the graph we can see the analysis with and without implementation of scheme for static model. The collision free transmission results in higher throughput for WLAN and WPAN nodes. After implementation of the scheme throughput is increased by 16.8%.

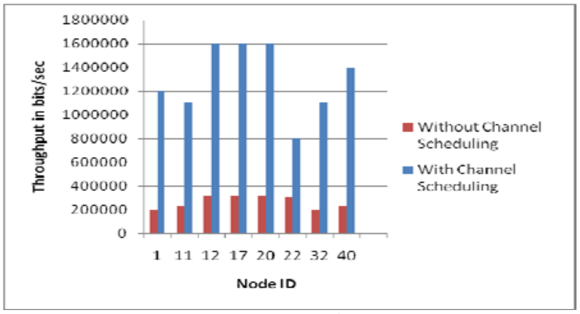


Fig: 3.d Throughput analysis for Grid Topology

Figure 3.e shows the average end-end delay for Grid Topology. After implementation of the scheme the average end-end delay has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for static model. After implementation of the scheme average end-end delay is decreased by 3%.

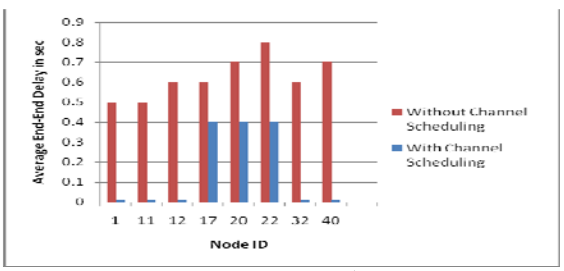


Fig: 3.e Average End-End analysis for Grid Topology

Figure 3.f shows the average jitter for Grid Topology. After implementation of the scheme the average jitter has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for static model. After implementation of the scheme average jitter is decreased by 5%.

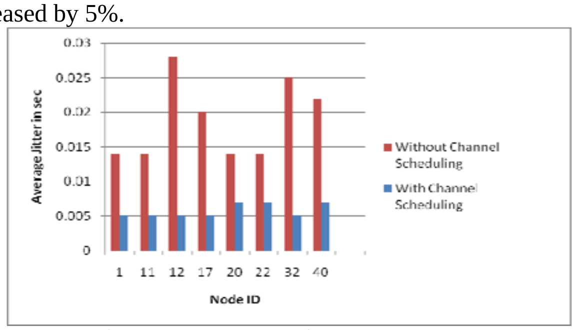


Fig: 3.f Average Jitter analysis for Grid Topology

The figure 4(a-f) shows the performance of 802.15.4 network for the three different metrics by utilizing the scheme for mobility model. The mobility model chosen is random way point with speed varying between 0 and 1m/s.

Figure 4.a shows the throughput for random topology. After implementation of the scheme the throughput has been increased. Here in the graph we can see the analysis with and without implementation of scheme for mobility model. The collision free transmission results in higher throughput for WLAN and WPAN nodes. After implementation of the scheme throughput is increased by 16.8%.

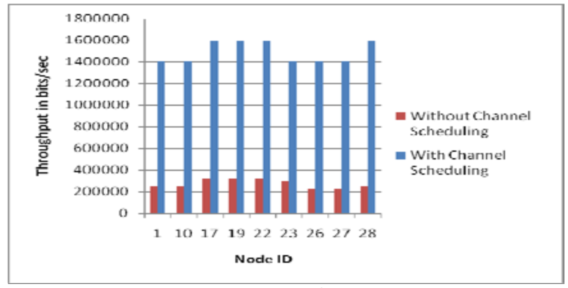


Fig: 4. a Throughput analysis for Random Topology

Figure 4.b shows the average end-end delay for random topology. After implementation of the scheme the average end-end delay has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for mobility model. After implementation of the scheme average end-end delay is decreased by 3%.

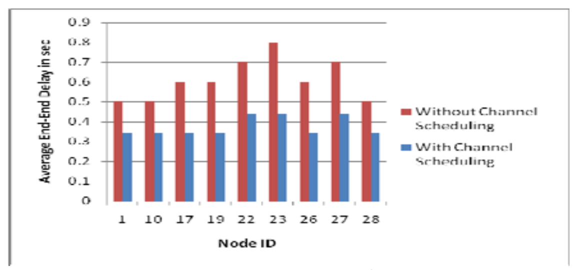
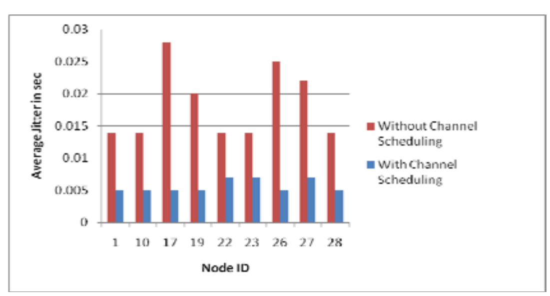


Fig: 4.b Average End-End delay analysis for Random Topology

Figure 4.c shows the average jitter for random topology. After implementation of the scheme the average jitter has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for mobility model. After implementation of the scheme Average Jitter is decreased by 5%.



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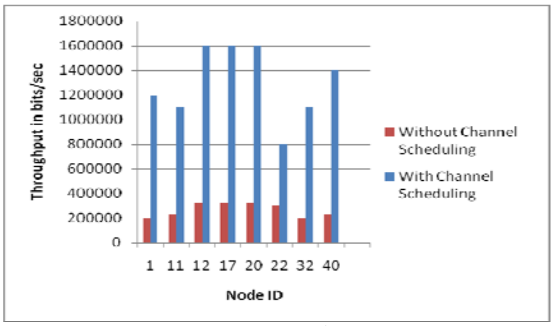

Fig: 4.d Throughput analysis for Grid Topology

Figure 4.e shows the average end-end delay for Grid Topology. After implementation of the scheme the average end-end delay has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for mobility model. After implementation of the scheme average end-end delay is decreased by 3%.

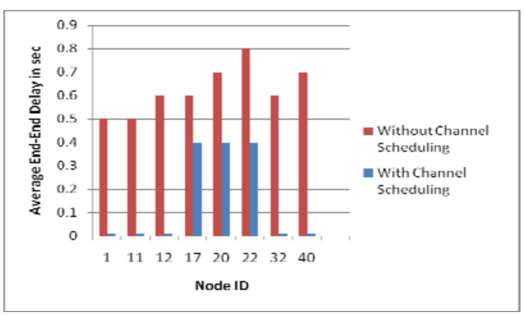

Fig: 4.e Average End-End analysis for Grid Topology

Figure 4.f shows the average jitter for Grid Topology. After implementation of the scheme the average jitter has been decreased. Here in the graph we can see the analysis with and without implementation of scheme for mobility model. After implementation of the scheme average jitter is decreased by 5%.

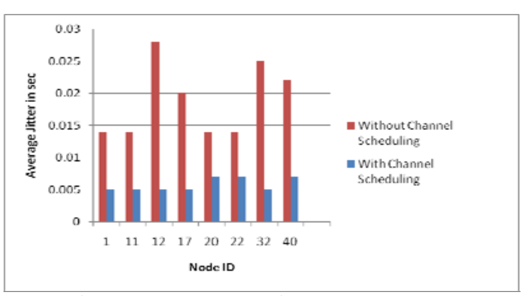

Fig: 4.f Average Jitter analysis for Grid Topology

V.CONCLUSION AND FUTURE WORK

We in this paper have analyzed the performance of coexistence heterogeneous networks, where we propose a new scheme using channel scheduling for the coexistence of IEEE 802.15.4 WPAN and IEEE 802.11b WLAN. The performance metrics of IEEE 802.15.4 network such as throughput, average end-end delay and average jitter is analyzed when the nodes are under static and mobility mode. The simulation results show that the proposed scheme is effective in performance improvement for coexistence network of IEEE 802.15.4 for random and grid topologies. In future, the analysis can be extended for random topology and the same scheme can be implemented in Exata emulator.

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