

Cluster Reformation and Scheduling for Interference Mitigation in Coexistence Heterogeneous Wireless Packet Networks

G.M.Tamilselvan¹, Dr.A.Shanmugam²

GJGST Classification (FOR)
C.2.1

Abstract - The emerging IEEE 802.15.4 (Zigbee) standard is designed for low data rate, low power consumption and low cost wireless personal area networks (WPANs). In ubiquitous networking environments; we generally need two or more heterogeneous communication systems coexisting in a single place. Especially, wireless local area networks (WLANs) based on IEEE 802.11b specifications and wireless personal area networks (WPANs) based on IEEE 802.15.4 specifications need to coexist in the same Industrial, Science and Medical (ISM) band. If the WPAN communication coverage is expanded using a cluster-tree network topology, then the 802.15.4 network is more susceptible to interference from neighboring WLANs. In this paper, we propose an adaptive transmission power aware cluster reformation and scheduling algorithm using multiple channels in a WPAN in the presence of WLAN interference. The algorithm includes node identification, channel allocation, cluster reformation and time scheduling. To evaluate the performance of the proposed algorithm, the performance metrics such as Packet Error Rate (PER), Throughput, Average End-End Delay and Average Jitter is measured through Qualnet simulation. PER is calculated from bit error rate. The simulation results are compared with the conventional TDMA scheme. The measurement result shows that the proposed algorithm is effective in an IEEE 802.15.4 cluster-tree network in the presence of multiple IEEE 802.11 interferers.

Keywords-Clustering, Coexistence, Heterogeneous, Packet Error Rate (PER), WLAN and WPAN (Zigbee).

I. INTRODUCTION

As a low-power and low-cost technology, IEEE 802.15.4 is establishing its place on the market as an enabler for the emerging wireless sensor networks (WSNs) [1]. Like IEEE 802.11b and IEEE 802.11g, IEEE 802.15.4 is also used in the 2.4 GHz ISM band. Due to supporting complimentary applications, they are very likely to be collocated within the interfering range of each other and therefore their ability to coexist needs to be evaluated. In this paper we focus on the coexistence between these two major wireless standards that operate in the 2.4GHz ISM band. Their overlapping frequency channels are shown in energy and is designed for low rate, low cost applications over a short range of 30 to 100 meters. The IEEE 802.15.4

About²-Principal BannaiAmman Institute of Technology, Sathyamangalam-638401, India tamiltamil@rediffmail.com, dras@yahoo.com

Fig. 1. IEEE 802.15.4 defines the physical layer and the MAC sub layer of the OSI Zigbee stack. It supports devices that consume minimum defines three physical layers; the 2.4 GHz, 868 MHz and 915 MHz frequency bands. The unlicensed industrial scientific medical (ISM) 2.4 GHz band is available worldwide, while the 868 MHz and 915 MHz bands are available in Europe and North America respectively. A total of 27 channels with three different data rates are defined for the IEEE 802.15.4: 16 channels with a data rate of 250 kbps at the 2.4 GHz band, 10 channels with a data rate of 40 kbps at the 15 MHz band, and 1 channel with a data rate of 20 kbps at the 868 MHz band. The relationship between the IEEE 802.11b (non-overlapping sets) and the IEEE 802.15.4 channels at the 2.4 GHz is illustrated in Fig.1

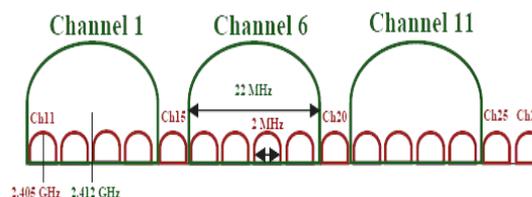


Fig.1.802.11 and 802.15.4 channels in the 2.4GHz ISM band

Figure 1 shows the operation frequency spectrum of both IEEE 802.11 and IEEE 802.15.4 networks in the 2.4 GHz ISM band. The IEEE 802.11 standard has 11 channels each of which occupies 22 MHz and up to 3 channels can be used simultaneously without mutual interference. As illustrated in the figure, channels 1, 6 and 11 can be used by the IEEE 802.11 devices to eliminate the mutual interference. On the other hand, the IEEE 802.15.4 standard defines 16 channels (2 MHz), channels 11 through 27, in the 2.4 GHz ISM band all of which can be used simultaneously without mutual interference. The IEEE 802.15.4 standard recommends using the channels that fall in the guard bands between two of the three adjacent non-overlapping IEEE 802.11 channels or above these channels to prevent interference between the IEEE 802.15.4 and the IEEE 802.11. From the figure, it is

About¹-Senior Lecturer, Department of ECE,

shown that 4 of the 11 channels will have the minimal interference which in most cases is enough to cover a big region unless more IEEE 802.15.4 networks are added. There have been some studies about coexistence between the IEEE 802.11b and IEEE 802.15.4. According to [1] [2] [4] IEEE 802.15.4 has a little impact on the IEEE 802.11 performance. However, IEEE 802.11 can have a serious impact on the IEEE 802.15.4 performance if the channel allocation is not carefully taken into account [1] [3]. While the conclusion is true in general, we believe the studies so far have dealt with only limited cases of coexistence scenarios. In [3], the Packet Error Rate (PER) of IEEE 802.15.4 under the IEEE 802.11b interference is analyzed from an assumption of blind transmissions, i.e. both IEEE 802.11b and IEEE 802.15.4 transmit packets regardless of whether the channel state is busy or not. In [4], measurements are performed to quantify coexistence issues. Channel Conflict Probabilities between IEEE 802.15 based Wireless Personal Area Networks is modeled in [5]. Packet Error Rate of IEEE 802.15.4 under IEEE 802.11b interference is analyzed in [6]. In [7] Packet Error Rate of IEEE 802.11b under IEEE 802.15.4 interference is analyzed. In [8] channel conflict probabilities between IEEE 802.11b and IEEE 802.15.4 have been modeled. In [9] channel collision between IEEE 802.15.4 and IEEE 802.11b for circular and grid topology is analyzed with the mobility model. The effect of inter packet delay is analyzed in [10]. The author concluded that despite its low transmit power and simple modulation technique, IEEE 802.15.4 shows a robust behavior against interference of other 2.4 GHz systems and even in the worst case conditions for frequency overlap, local distance and high traffic load for interference, some time slots remain for a successful transmission of IEEE 802.15.4. In above said related works only two WPAN nodes which are collocated with multiple WLAN nodes are considered. But today the sensor networks play a vital role in any automation; we have to consider the multiple WPAN nodes. When multiple sensor nodes are used, time slot mechanism is not helpful in WPAN network because ZigBee is a mesh networking technology. The remainder of the paper is organized as follows: Section II gives an overview of the IEEE 802.11b and IEEE 802.15.4 standard. Section III presents a heterogeneous wireless network with conventional TDMA scheme for packet transmission and cluster tree network with two different time and frequency scheduling schemes. Simulation results are shown in Section IV. Our conclusion is drawn in Section V.

II. OVERVIEW OF IEEE 802.11B AND IEEE 802.15.4

1) IEEE 802.11b

IEEE 802.11b standard defines the Medium Access Control (MAC) sub layer and the Physical (PHY) layer for wireless LANs. The standard operates at 13 overlapping channels in the 2.4 GHz ISM band and the bandwidth of each channel is 22 MHz. IEEE 802.11b MAC employs the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism. Before initiating a transmission, an IEEE

802.11b node senses the channel to determine whether another node is transmitting. If the medium is sensed idle for a Distributed coordination function Inter-Frame Space (DIFS) time interval the transmission will be preceded. If the medium is busy the node defers its transmission. When the medium becomes idle for a DIFS interval, the node will generate a random back off delay uniformly chosen in an interval. This interval $[0, W]$ is called Contention Window, where W is the size of the contention window. The initial W is set to CW_{min} . The back off timer is decreased by one as long as the medium is sensed idle for a back off time slot. The back off counter will become frozen when a transmission is detected on the medium, and resumed when the channel is sensed idle again for a DIFS interval. When the back off timer reaches zero, the node transmits a DATA packet. Immediately after receiving a packet correctly, the destination node waits for a Short Inter Frame Spacing (SIFS) interval and then transmits an ACK back to the source node.

2) IEEE 802.15.4

The IEEE 802.15.4 MAC sub layer is based on CSMA/CA (channel sense multiple access) with two modes of operation: the unslotted-CSMA (beaconless mode) and the slotted-CSMA (beacon enabled mode). The basic responsibilities for the MAC sub layer is transmitting beacon frames, synchronization and providing a reliable transmission between Zigbee devices. Link layer acknowledgments are optional in IEEE 802.15.4 which can provide extra link level reliability. For our simulations, the unslotted-CSMA is used as all sources will be continuously contending for the channel. Link layer acknowledgments are used in order to make the transmission more reliable. To minimize the energy consumption of the Zigbee nodes, the slotted CSMA/CA should be taken into consideration since it uses beacon frames that contain information about when nodes can go into sleep mode. However, this is beyond the scope of this paper.

III. PROPOSED SCHEME

In this paper, we propose power aware time slot and frequency based spectrum access analysis for the performance metrics such as bit error Rate, PER, throughput, average End-End delay and average jitter of IEEE 802.15.4. In this proposed scheme the WPAN devices are clustered. Each cluster will have one PAN coordinator and four end devices. We consider a heterogeneous network with random topology. IEEE 802.15.4 topologies are shown in Fig.2 Here the performance of IEEE 802.15.4 under the interference of IEEE 802.11b and the interference among IEEE 802.15.4 nodes because of multiple transmissions is analyzed using Qualnet 4.5 simulation. For simulation, the unslotted CSMA/CA of the IEEE 802.15.4 model is developed using Qualnet 4.5. The random topology scenario of coexistence heterogeneous network with 20 WPAN and 20 WLAN nodes for heterogeneous wireless network with

conventional TDMA scheme and two different scheduling schemes are shown in Fig.4 ,5&6 respectively.

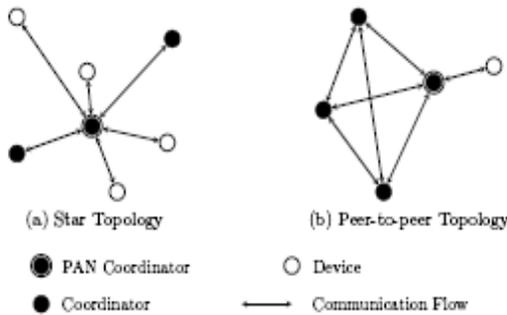


Fig.2. IEEE 802.15.4 Topologies

The PHY of the IEEE 802.15.4 at 2.4 GHz uses offset quadrature phase shift keying (OQPSK) modulation. Denote that the E_b / N_0 is the ratio of the average energy per information bit to the noise power spectral density at the receiver input, in the case of an additive white Gaussian noise (AWGN) channel. Then the bit error rate (BER), P_B , can be expressed as

$$P_B = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \tag{1}$$

Where $Q(x)$ is

$$Q(x) = \frac{1}{\sqrt{x}} \int_x^\infty \exp\left(\frac{-u^2}{2}\right) du \tag{2}$$

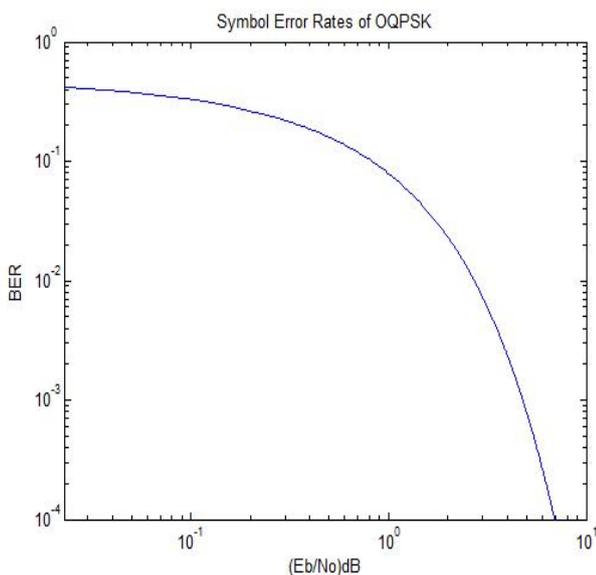


Fig.3: Theoretic Bit Error Rate of OQPSK

Fig.3 shows the relationship between the bit error rate and E_b / N_0 simulated in Matlab. The bit error rate decreases when E_b / N_0 increases. The noise power spectral density increases when collision increases. As the number of WLAN sources increases, the BER of IEEE 802.15.4 increases because contentions among multiple WLANs increase the channel usage and cause collisions, which is more powerful interference, source to.

The PER is calculated as a function of the BER, i.e., P_b . The probability of not having a bit error is the probability that all the bits are received correctly. Therefore the conditional probability of PER is one minus the probability of no bit errors and is computed as follows:

$$PER = 1 - \left(1 - P_b\right)^N \tag{3}$$

where N represents the number of bits in a packet. For the experimental setting each packet is composed of 105 bytes in the case of WPAN node and 1500 bytes in the case of WLAN node. If there is an error correction mechanism, then the PER utilizing the BER should be computed differently. However, the experimental platform does not provide an error correction mechanism and Equation 3 is the final form of the PER.

In this paper conventional TDMA scheme and two clusters based scheduling schemes are proposed and the results are compared. In cluster based scheduling the first scheme is called inter cluster scheduling. In this scheme the nodes are separated based on their transmission power. The output power of 802.15.4 devices is typically as low as 0 dBm , whereas the output power of 802.11b devices is 15 dBm or above. Then WLAN nodes are grouped under one operating frequency and WPAN nodes are clustered with cluster size 5.Each cluster will have one PAN coordinator and four end devices. Each cluster is allotted unique channel frequency for error free transmission. After frequency scheduling, in each channel specific time slot is allotted for packet transmission.In second scheme the new cluster is formed from the existing clusters and scheduling is done. The cluster members from different clusters are grouped under one channel and specific time slots are allotted for packet transmission. The figure 4, 5 & 6 shows the scenario for heterogeneous network with conventional TDMA scheme and two different clusters based scheduling schemes respectively.

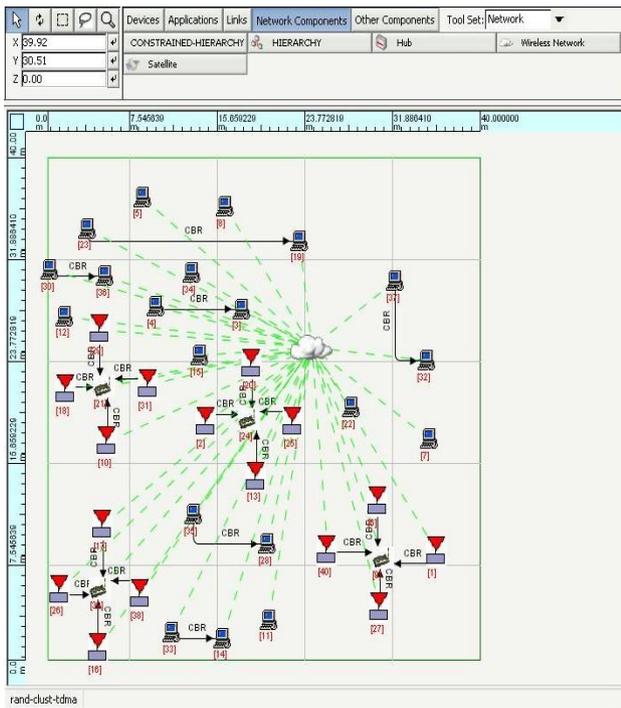


Fig.4.Random topology scenario with Conventional TDMA

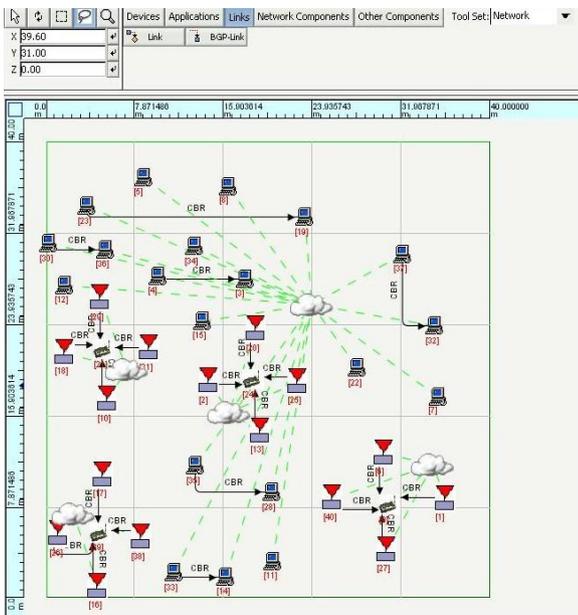


Fig.5.Random topology scenario with Inter cluster Scheduling

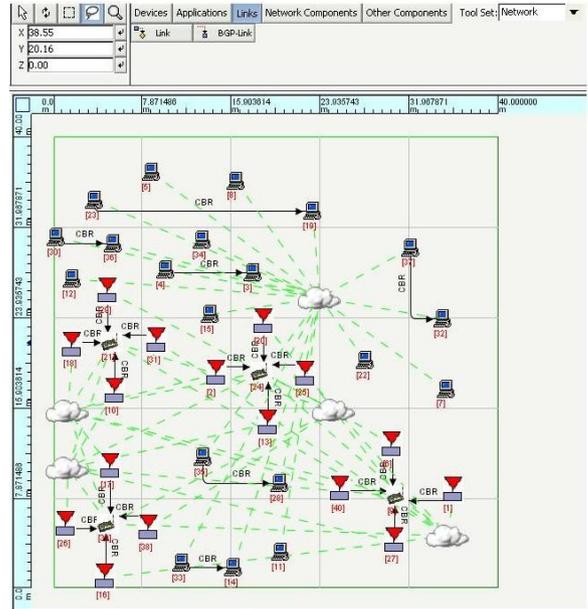


Fig.6.Random topology scenario with Reformed cluster Scheduling

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 is conducted for three different schemes and the results are compared. The bit error is measured from the simulation. The bit error rate is calculated to find packet error rate (PER). For the conventional TDMA scheme all the nodes are linked with single channel and time slots are allotted for transmission. For this scheme the simulation time is fixed as 53s. The simulation configuration and parameters used in this paper is shown in Table 1.

TABLE 1.
SIMULATION CONFIGURATION AND PARAMETERS

Parameter	IEEE 802.11b	IEEE 802.15.4
Number of Nodes	20	20
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	
Packet Interval	100ms	1ms
Packet Transmission Time	5s	1s
Test bed size	40m × 40m	
Topology	Random	

The effectiveness of the proposed scheme was measured with different metrics such as Bit error rate, Packet Error rate, Throughput, Average End-End delay and Average jitter. The figure 7-11 shows the performance analysis of random topology with two different proposed schemes. The fig.7 shows the bit error rate analysis for random topology. In this figure bit error rate for conventional TDMA and two different schemes namely inter cluster scheduling and Reformed cluster scheduling is shown. When the reformed cluster scheduling is adopted the bit error rate becomes zero. When the conventional TDMA and inter cluster scheduling is adopted, time slot mechanism is not helpful in WPAN network because ZigBee is a mesh networking technology, which means that devices can automatically route messages on each other's behalf (often called multi-hopping). This allows deploying larger networks without immoderately increasing the transmission power since direct communications occur only in a geographically-restricted area.

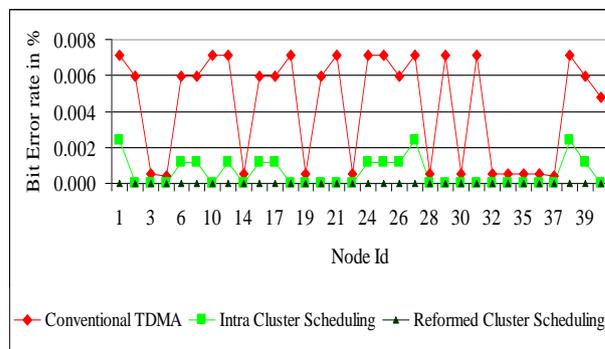


Fig .7.Bit Error Rate Analysis for Random Topology

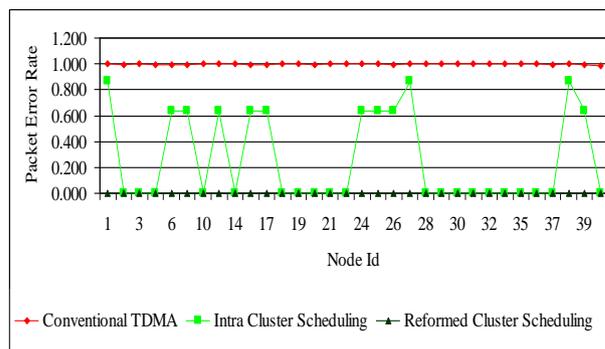


Fig.8.Packet Error Rate Analysis for Random Topology

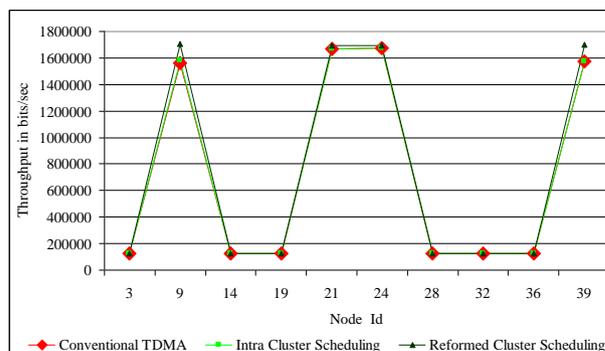


Fig .9.Throughput Analysis for Random Topology

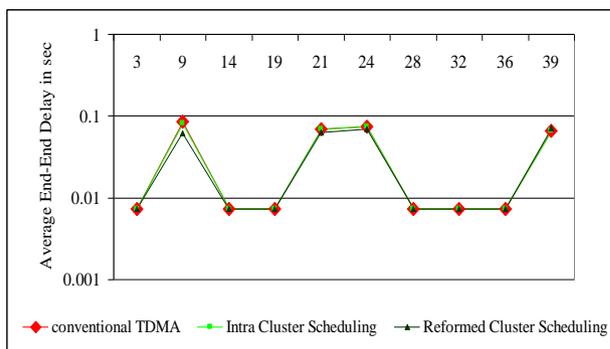


Fig .10.Average End-End Delay Analysis for Random Topology

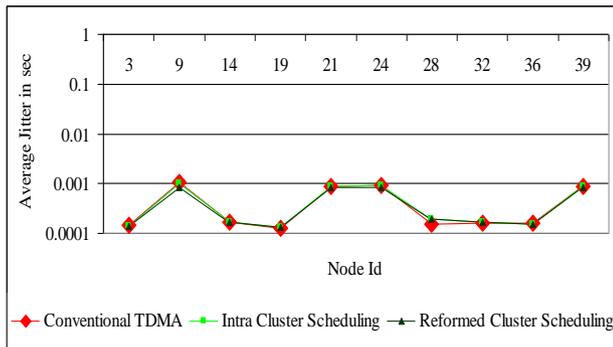


Fig .11.Average Jitter Analysis for Random Topology

V. CONCLUSION

We in this paper present analysis on performance of coexistence heterogeneous networks. In this paper, we propose a new power based scheme using inter & reformed cluster scheduling mechanism for the coexistence of multiple IEEE 802.15.4 LRWPAN and IEEE 802.11b WLAN. The performance metrics of IEEE 802.15.4 network such as bit error rate ,throughput, average end-end delay and average jitter is analyzed when the nodes are static. The simulation results show that the proposed scheme is effective in performance improvement for coexistence network of IEEE 802.15.4 for random topology. In future the analysis can be extended with mobility model and the same proposed scheme can be implemented with Exata emulator.

VI. REFERENCES

- 1) M. Petrova, *et al*, "IEEE 802.15.4 Low Rate - Wireless Personal Area Network Coexistence Issues," *Proc. IEEE WCNC'06*, Las Vegas, USA
- 2) I. Howitt and J. A. Gutierrez, "Low-Rate Wireless Personal Area Networks - Enabling Wireless Sensors with IEEE 802.15.4," *Proc. IEEE WCNC'03*, vol.3, pp. 1481-1486
- 3) S. Shin, *et al*, "Packet error rate analysis of IEEE IEEE 802.15.4 under IEEE 802.11b interference," *Proc. WWIC'05*, pp. 279-288
- 4) A. Sikora, "Coexistence of IEEE 802.15.4 (ZigBee) with IEEE 802.11 (WLAN), Bluetooth, and Microwave Ovens in 2.4 GHz ISM-Band," *web document*, <http://www.ba-loerrach.de/stzedn/>
- 5) Ling-Jyh Chen, Tony Sun, Mario Gerla, "Modeling Channel Conflict Probabilities between IEEE 802.15 based Wireless Personal Area Networks", *Communications, 2006. ICC apos; 06. IEEE International Conference on Vol.1, Issue, June 2006 Page(s):343 - 348*

- 6) Soo Young Shin, Hong Seong Parky, Sunghyun Choi, Wook Hyun Kwon," Packet Error Rate Analysis of IEEE 802.15.4 under IEEE 802.11b Interference", *IEICE Transactions on Communications 2007*
- 7) Dae Gil Yoon, Soo Young Shin, Wook Hyun Kwon and Hong Seong Park," Packet Error Rate Analysis of IEEE 802.11b under IEEE 802.15.4 Interference" **Vehicular Technology Conference, 2006. VTC 2006-Spring. IEEE 63rd** Publication Date: 7-10 May 2006 Volume: 3, On page(s): 1186-1190
- 8) G.M.Tamilselvan, Dr.A.Shanmugam, "Modeling Channel Conflict Probabilities and Interference analysis of Coexistent Heterogeneous Networks" *International Journal of Computer science and Knowledge Engineering (IJCSKE)*, Vol 3.Jan-June 2009, on page(s): 113-118
- 9) G.M.Tamilselvan,Dr.A.Shanmugam, "Probability Analysis of Channel Collision between IEEE" *International Journal of Computer Theory and Engineering(IJCTE)*, Vol. 1, No.1, April 2009,On page(s):59-64
- 10) G.M.Tamilselvan, Dr.A.Shanmugam, "Effect of Inter Packet Delay in Performance Analysis of Coexistence Heterogeneous Wireless Packet Networks", *International Journal of Network Security and Applications (IJNSA)*, Vol 1, No 2, July 2009, On Page(s):40-49
- 11) .