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COEXISTENCE MODEL OF ZIGBEE& IEEE 802.11b (WLAN) IN UBIQUITOUS NETWORK ENVIRONMENT

Neha Gandotra, Vishwanath Bijalwan, Manohar Panwar

***Abstract*— IEEE 802.15.4 standard is used for low rate, short distance wireless communication. However due to its low power it is greatly affected by interference provided by other wireless technology working on same ISM(industrial, scientific & medical) band, such as IEEE 802.11b/g & Bluetooth. In ubiquitous network environment we have two different heterogeneous communication systems coexists in single place. In this paper we use an analytic model and an experimental set up for the coexistence among Zigbee, &WLAN. The model focuses on two aspects, namely Power & Timing. These two jointly impacts on the performance of IEEE 802.15.4 wireless network. Zigbee is main component of wireless sensor network, so therefore to study about performance of network should be need in interference environment.**

***Index Terms*— CCK, CCA, IEEE 802.15.4 Zigbee, PER, IEEE 802.11b (WLAN),**

INTRODUCTION

Ubiquitous networking allows many devices or objects to connects and communicate with each other. IEEE 802.15.4 (Zigbee) [2] is low rate wireless personal area network. It uses unlicensed 2.4 GHz ISM band. Its major applications in Wireless sensor networks, Home automation, medical instruments and RF4CE (radio frequency for consumer electronics).Because Zigbee, IEEE 802.11b and Bluetooth network operates on same ISM band, which causes significant interference on Zigbee network.

Zigbee is low cost, low power wireless mesh networking standard. Low cost allows the technology to be widely used in sensor network as monitoring and control. Low power allows longer battery life of device, and mesh networking allows high reliability and more wide range. IEEE802.15.4 specification describes 3 topologies: Star, Peer-to-Peer, and cluster-tree topology.

I. IEEE 802.15.4 AND IEEE 802.11B OVERVIEW

Zigbee is based on IEEE 802.15.4 standard defines 16 channels which are 5 MHz apart from each other and having bandwidth of 2 MHz each channel. It uses OQPSK modulating scheme with half pulse shaping. Zigbee uses data rates of 250kbps, 40 kbps and 20 kbps. It supports low latency devices. Zigbee uses dynamic device addressing and use fully handshake protocol for transfer reliability. It has extremely low duty cycle (<0.1%). IEEE 802.11b [1]and zigbee both uses CSMA/CA [5] for media access control, and most important zigbee uses interference mitigation mechanism (DSSS and "listen before send").Zigbee focus on low power consumption and low data rates. It also provides reduced complexity and device size.802.15.4 technology is mature, basis of commercial products. Zigbee has multi-level security and works well for long battery life, selectable latency for controllers, sensors, remote monitoring and portable electronics. Because operating frequency band is same for WLAN, and Bluetooth (IEEE 802.15.1), which causes degradation on QOS, and packet delivery performance of Zigbee. WLAN (IEEE 802.11b standard defines the MAC and PHY sub layer for wireless LAN. This standard operates on 13 overlapping channel in 2.4GHz ISM band having bandwidth of each channel is 22 MHz This standard also use Carrier Sense multiple Access with collision avoidance mechanism. Channel sensing is important to determine whether another node is transmitting or not, before transmission. For getting higher data rate we use 8-chip complementary code keying scheme (CCK) as modulation scheme. Before transmission IEEE 802.11b [1][2] node sense the channel, is another node transmitting or not? If the medium is sensed idle for distributed coordination function inter-frame space (DIFS) time interval then transmission will start. Also if medium is sensed busy then node discards its transmission. So during idle mode for DIFS interval, node will generate a random backoff [2] delay in [0, W]. This time interval is known as contention window, where W is size of contention window. Minimum value of W is CW_{min} which is initially set. The backoff timer is decremented by one as long as medium is sensed idle for backoff time slot. Backoff counter is off when transmission is detected and resumed when channel is sensed idle again. When backoff timer is reached to zero, the node transmits a DATA packet. After receiving a data packet, destination node waits for a short inter frame spacing (SIFS) interval and then immediately transmits ACK signal back to the sender or source node. Table 1 shows different parameters of IEEE 802.11b and IEEE 802.15.4 network. Table shows different parameter values e.g. transmit power, receiver sensitivity, payload size etc. In IEEE 802.15.4 channel is not sensed during backoff period but sensed in clear channel assessment (CCA) period. Also contention window in IEEE 802.15.4 is doubled when the channel is busy

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during CCA. In IEEE 802.11b contention window is same when channel is busy but get doubled when ACK is not received. Figure 1 shows the spectrum of IEEE 802.11b and IEEE 802.15.4 network.

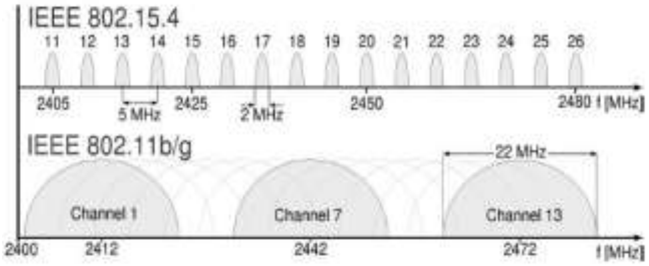

Fig 1. IEEE 802.15.4 and IEEE 802.11 spectrum usage in 2.4 GHz ISM band

In terms of transmission we know that transmission power of WLAN is 100 times larger than that of Zigbee networks, so that's why we focus on interference from WLAN to Zigbee.

Parameters	IEEE 802.11b	IEEE 802.15.4
Transmit Power	20dBm	0dBm
Receiver Sensitivity	-76dBm	-85dBm
Transmit Rate	11 Mbps	250 Kbps
Bandwidth	22 MHz	2 MHz
Back off unit T_{bs}	20 µs	320 µs
SIFS	10 µs	192 µs
DIFS	50 µs	N/A
CCA	N/A	128 µs
CW_{min}	31	7
Center Frequency	2412 MHz	2410 MHz
Payload Size	1024 bytes	1 byte

Table 1: IEEE 802.15.4 and IEEE 802.11b System parameters and some other parameters

II. Coexistence Model of 802.11b and IEEE 802.15.4

The coexistence assurance Methodology predicts the PER of an affected wireless network (AWN, or victim) in the presence of an interfering wireless network (IWN, or assailant). Method says that an AWN and an IWN each composed of a single transmitter and receiver. The method takes as input a path loss model, a BER function for the AWN, and predicted temporal models for packets generated by the AWN and packets generated by the IWN. The method predicts the PER of the AWN as a function of physical spacing between the IWN transmitter and the AWN receiver. Coexistence can be seen by these three parameters.

- Bandwidth of AWN and IWN devices.
- BER as a function of SIR of AWN devices.
- Path loss model for the network.

915 MHz O-QPSK PHY

At 915 MHz IEEE 802.15.4 uses O-QPSK modulation uses a chip rate of R_c of 1000 k_c/s bit rate R_b of 250 kb/s and a code block of M=16 symbols [1]. Conversion from SNR to E_b/N_0 assume matched filtering and half pulse shaping.

$$\frac{E_b}{N_0} = \frac{.625 R_c}{R_b} SNR = \frac{.625 \times 1000000}{250000} = 2.5 \text{ SNR} \quad (1)$$

Converting bit noise density E_b/N_0 to symbol noise density E_s/N_0.

$$\frac{E_s}{N_0} = \log_2(M)\frac{E_b}{N_0} = 4\frac{E_b}{N_0} \quad (2)$$

SER P_s is computed for non coherent MFSK

$$P_s = \frac{1}{M}\sum_{j=2}^{M}(-1)^j \binom{M}{j} \; exp\left(\frac{E_s}{N_0}\left(\frac{1}{j}-1\right)\right) \quad (3)$$

Finally converting P_s to BER P_b

$$P_b = P_s\left(\frac{M/2}{M-1}\right) = P_s\left(\frac{8}{15}\right) \quad (4)$$

Rolling these together produces BER function.

$$P_b = \left(\frac{8}{15}\right)\left(\frac{1}{16}\right)\sum_{j=2}^{M}(-1)^j \binom{16}{j} exp\left(10SNR\left(\frac{1}{j}-1\right)\right) \quad (5)$$

Temporal Mode

All packets are assumed 32 bytes whether belongs to AWN or IWN and maximum PSDU size should be 128 bytes. It is assumed that all 915 MHz devices have whether operating AWN or IWN have duty cycle should high nearly equal to 10%.

Packet size of 32 bytes and duty cycle of 10%, the channel will occupied for

$$\frac{\text{packet size} \times 8}{\text{bits per second}} = \frac{256}{250000} \text{ S} = 1.024\text{ms} \quad (6)$$

Channel will idle for 90 x 1.024 = 92.16 ms

Coexistence method results

Figure 6 shows coexistence methodology results for 915 MHz O-QPSK PHY

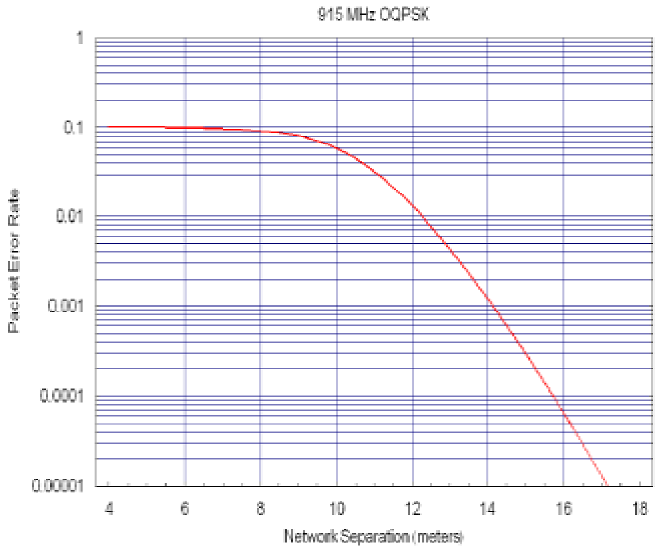

Fig 2. Coexistence results for 915 MHz O-QPSK PHY

We assume saturated IEEE 802.11b interference in our work. Under WLAN interference Zigbee packet is successfully received if one of the below conditions is satisfied.

(a) When IEEE 802.15.4 packets overlaps WLAN (b) packet the in band interference power from the WLAN packet is lower than the IEEE 802.15.4 packet at an IEEE 802.15.4 receiver. According to specification, if interference is weak enough so that the in band (signal to interference ratio) SIR is greater than 5-6dB, an IEEE 802.15.4 packet is successfully received with a probability of 99%.

(b) The transmission time of IEEE 802.15.4 packet is less than the inter frame idle time (T_{idle}) between two nearer WLAN packets so that IEEE 802.15.4 packet will not overlap WLAN packet.

Our model involves two aspects, namely Power & Timing.

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Power Aspect:

We use a path loss model recommended in IEEE 802.11b specification, for determining a power of received signal in free space propagation.

We know that transmission power of IEEE 802.11b and 802.15.4 nodes are different. The difference in transmit power and receiver sensitivity leads to different ranges R_1,R_2, and R_3.

We quantify these ranges accordingly

R_1 : In this range both IEEE 802.15.4 node and IEEE 802.11b both nodes can sense each other,

R_2 : In this range IEEE 802.15.4 node can sense IEEE 802.11 node but not vice versa,

R_3 : In this range both nodes can't sense each other but IEEE 802.15.4 node still suffers interference.

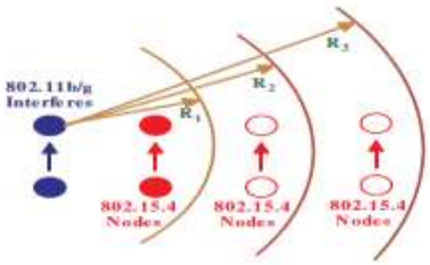

Fig 3: Coexistence ranges of IEEE 802.11b and IEEE 802.15.4

The path loss follows free space propagation up to 8m and then attenuates rapidly with coefficient of 3.3 which is taken 4 in accordance with 32m indoor transmission distance of IEEE 802.15.4 nodes.

The path loss[2] [8] is given as:

$$PL(d) = \begin{cases} 20\ log_{10}\left(\frac{4\pi d}{\lambda}\right) & if\ d \le do \\ 20\ log_{10}\left(\frac{4\pi do}{\lambda}\right) + 40\ log_{10}\left(\frac{d}{do}\right) & if\ d > do \end{cases} \quad (7)$$

Here d= distance between transmitter and receiver, do is the length of line of sight =8m

We assume here that Power spectral density of WLAN is uniformly distributed across 22 MHz bandwidth, also taking receiver sensitivity as received power and SIR at 6dB.

Table II

Coexistence Ranges of IEEE 802.15.4 AND IEEE802.11b/g

Ranges	IEEE 802.11b	IEEE 802.11g
R_1	22m	32m
R_2	67m	67m
R_3	95m	95m

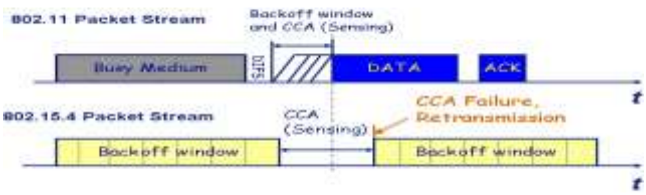

Fig 4: In Range R_1 IEEE 802.11b/g nodes have priority over IEEE 802.15.4 nodes

So based upon above ranges we have 3 scenario for determining the throughput.

Timing Aspect:

Range R_1 : In this scenario CSMA/CA mechanism works of both standards, therefore one is transmitting and other has to wait. We know that IEEE 802.15.4 nodes have 10-20 times longer timing than WLAN nodes. Shorter timing gives IEEE 802.11b nodes priority over IEEE 802.15.4 nodes and therefore interference arise to IEEE 802.15.4 nodes. Sufficient coexistence condition for this range R_1 is that CCA [8] of IEEE 802.15.4 happens during idle time of two consecutive IEEE 802.11b packets. Scenario is shown in fig 3.

$$t_{idle} \triangleq DIFS + t_{bo} = DIFS + m.T_{bs} \quad (8)$$

Where T_{bs} is backoff unit, m is random inter uniformly distributed over [0,CW_{min}],

t_{bo} is random period for an additional deferral time before transmitting.

When m≥ 4 for IEEE 802.11b, t_{idle} ≥ CCA.

Thus value of m should be taken in [4, 31], t_{idle} is long enough for performing CCA.

RangeR_2: In this range IEEE 802.11b nodes are transmitting and IEEE 802.15.4 nodes are waiting, but when IEEE 802.15.4 nodes are transmitting, IEEE 802.11b nodes are not aware and try to transmit, which cause overlapping in packets transmission. This is shown in fig 4.

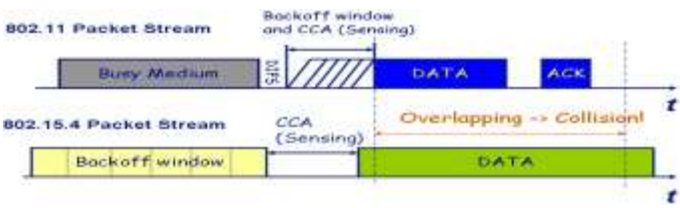

Fig 5. In Range R_2 IEEE 802.11b nodes fail to sense IEEE 802.15.4 nodes

In this scenario to ensure non overlapping transmission the below condition must be satisfied.

$t_{idle} \triangleq DIFS + m.T_{bs} \geq CCA + t_p + SIFS + ACK$ t_p is the transmission time of an IEEE 802.15.4 packet.

For successful transmission of IEEE 802.15.4 equation (7) should be satisfied.

Range R_3 **:** In this range neither IEEE802.11b nodes nor IEEE 802.15.4 nodes can sense each other. But IEEE802.15.4 nodes can still suffer interference from IEEE802.11b nodes, because a range where wireless devices can cause interference to other is usually larger than a range where it is sensed by other wireless devices. In this range both IEEE 802.11b and IEEE 802.15.4 node are transmitting without deferring each other, this means blind transmission is happening. Also for successful transmission of packets, power condition (7) should be satisfied. In case of ACK is not

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employed successful transmission of IEEE 802.15.4 packets could happen if and only if timing condition (8) is satisfied while power condition (7) is not necessary.
Thus by these 3 scenario we see that how interference is affecting the throughput of IEEE 802.15.4 network.

III. Experimental setup

We construct a experimental setup for measurement the throughput of IEEE 802.15.4 (zigbee) under WLAN interference. WLAN is constructed by two laptops and one WLAN access point. Zigbee network is constructed using Zigbee evaluation kit which contains one display board and three RCB (radio controller board). One RCB is mounted on display board which acts as Zigbee coordinator and other two RCB acts as zigbee end devices, these forms Zigbee network.

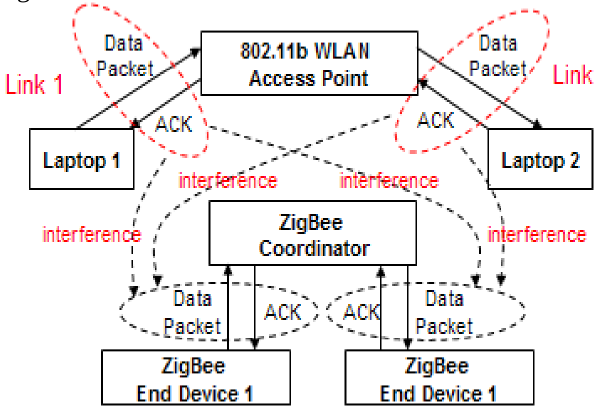

FIG. 6 MEASUREMENT SETUP

WLAN packets are continuously transmitting from one laptop to access point which sends data packets to another laptop.
Test case 1:-we conclude some facts from above fig.6.In frequency domain we know that signal power is concentrated around center frequency[6] and weaker away from the center. Suppose we choose 4 IEEE 802.15.4 channels overlapping with one WLAN channel with 2MHz, 3 MHZ, 7MHz, and 8MHz frequency offsets from WLAN channel center frequency then we investigate that IEEE 802.15.4 channel with 2 MHz offset is close to WLAN channel center frequency, That's why it suffer serious interference, and 8 MHz channel offset suffers least interference as an overlapping channel [6]. As conclusion, when the frequency offset is larger, the interference power is less, and impact is less [6]. See figure 7.

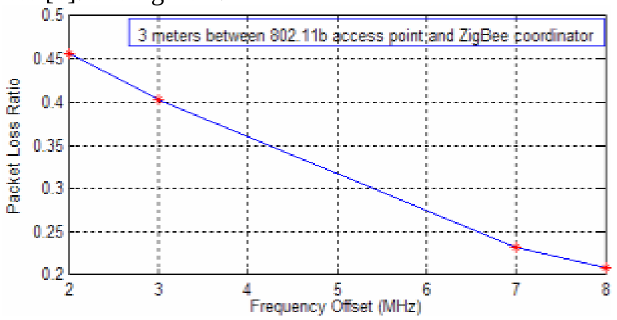

Fig. 7 Packet loss ratio when distance between Zigbee coordinator to WLAN (802.11b) Access point is 3 meters.

Test case 2:-Fixed zigbee network to work on two non-overlapping channels: 21(2455 MHz) and 16(2430 MHz)

We see that in a valid range interference (Packet loss ratio) decreases as the distance between WLAN access point and Zigbee coordinator increases. See figure 8.

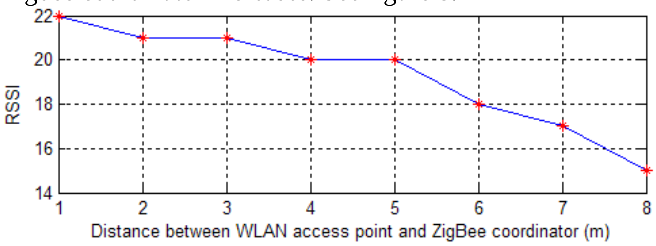

Fig.8 Received signal strength indication (RSSI) at zigbee coordinator

IV. CONCLUSION

Based upon model analysis and measurement setup we see how IEEE 802.15.4(Zigbee) network performance reduces in the IEEE 802.11b network environment.
Our Model suggests the different ranges for analysis of throughput in interference environment, and measurement suggests two different results which are shown in Test case 1 and 2. We conclude interference calculation on IEEE 802.15.4 in IEEE 802.11b network environment but we know that at 2.45 GHZ IEEE 802.15.3 and IEEE 802.11g network also works so that if the entire network exists in a valid range there will a significant drop in IEEE 802.15.4 network's Throughput. An optimum solution for this problem is that we can use adaptive interference-aware multi-channel clustering algorithm [7].

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REFERENCES

[1] IEEE 802.11b Specification, *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band, Sep. 16, 1999*
[2] IEEE 802.15.4 Specification, *Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs),* Oct. 1, 2003.
[3] Soo Young Sin, "Packet error rate analysis of zigbee under WLAN and Bluetooth interferences" *IEEE transaction on wireless communication, VOL. 6, NO. 8, August 2007*
[4] Khaled shuaib, "performance Evaluation of IEEE 802.15.4 Experimental and Simulation results" *Journal of communication VOL.2, NO.4, JUNE 2007*
[5] J.G. proakis, Digital communications, McGraw-Hill, 1995
[6] Guang Yang,"Zigbee network performance under WLAN 802.11b/g interference" *IEEE conference on Wireless pervasive computing, 2009, ISWPC 2009.11-13 Feb, 2009.*
[7] Min Suk Kang, "Adaptive Interference-Aware Multi-Channel Clustering Algorithm in a zigbee Network in the Presence of WLAN Interference" *IEEE conference on wireless pervasive computing, 2007, ISPWC. 5-7 FEB, 2007.*

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[8] Wei Yuan, "A Coexistence model of IEEE 802.15.4 and IEEE 802.11b/g" *14th symposium on communication and vehicular technology in Benelux, 2007*

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