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LOAD AWARE CHANNEL ESTIMATION AND CHANNEL SCHEDULING FOR 2.4GHZ FREQUENCY BAND BASED WIRELESS NETWORKS FOR SMART GRID APPLICATIONS

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Abstract - The advanced monitoring and control applications consider Wireless Sensor Networks (WSN) as a promising technology for modern applications like the Internet of Things (IoT), Smart Grid and Wireless Body Area Networks (WBAN). The WSN has important features like less cost, low power usage, supportable data rates and complexity. There is a need for continuous research on improving characteristics and abilities of WSN. The reliable performance of WSN depends on the latency necessities depending on the type of application and Quality of Service (QoS) parameters. The technologies like Zigbee, WiFi, and Bluetooth operating in 2.4GHz are mostly considered for deploying the WSN. Because of coexistence environment, the performance of Zigbee gets affected in terms of channel switching and causes the significant amount of delay. Also, the data transmission should be performed without any collision. In this paper, initially, the pseudorandom – based interference evading scheme is introduced for efficient data communication. During this scheme, if node attains a channel it must wait for a network reconfiguration time for moving to next channel. Hence, during this time other nodes are allowed for moving to the new channel. Secondly, for moving to the new channel load aware channel estimation is proposed to assess the possibility of traffic weight assignment at each channel. Finally, the Particle swarm optimization (PSO) based collision avoiding multiple-channel based superframe scheduling is proposed for IEEE 802.15.4 based wireless networks working under the influence of IEEE 802.11b network. The channel with best energy function is selected for data transmission. The work proposed in this paper is evaluated based on the comparison to the existing works. From the results obtained it is inferred as proposed work shows better performance in terms of packet error rate, packet delivery ratio, and energy consumed when compared to the existing algorithms.

Index terms: IEEE 802.15.4, IEEE 802.11b, Channel Scheduling, Coexistence, 2.4GHz ISM band, Packet Error Rate, Packet Delivery Ratio, Wireless Sensor Networks, Smart Grid.

I. INTRODUCTION

The WSN has been emerged due to their exponentially growing attention from both industry and academia [1]. WSN is regarded as an important technology for modern monitoring and controlling solutions. WSN is available at, low-cost and works with low-power requirements [2]. The growing interest on WSN is because of a growing number of emerging applications such as IoT [3], health care monitoring [4], home automation [5], Smart Grid [6][7], industrial automation [8], structural monitoring [9], environmental monitoring [10], and surveillance [11]. In addition to the IEEE 802.11b/g based wireless local area networks (WLAN's), certain low cost and low power wireless technologies are emerging based on IEEE 802.15.4 guidelines and support the applications working with lower data rate and low power communications.

The IEEE 802.15.4 protocol operates in two different modes. Firstly, network operates in the beacon-active mode then the data packet is scheduled in the terms of superframes based on the slotted CSMA/CA mechanism i.e., time is structured in certain beacon intervals. Secondly, network operates in non-beacon mode and the node retrieves the channel based on the unslotted CSMA/CA system or node shall be inactive (sleep mode). Each beacon interval is subdivided into active mode and inactive mode (sleep mode) [2]. ZigBee nodes work based on IEEE 802.15.4 standards. It is the short-range wireless networking medium with low cost, low latency, and operates with minimum Energy [12]. IEEE 802.15.4 has the transmission rates up to 256 Kbps at 2.4 GHz, operates with the communication range within 10m-75m. It is a reliable standard for wireless sensor applications in terms of communication overheads and energy efficiency. Some of the applications of 802.15.4 are cost sensitive and are mostly related to home area networks (HAN), control and automation, industries, PC peripherals, security, and medical monitoring IP [13].

The following are the advantages of IEEE 802.15.4 standard:

(1) Assures secured and reliable data transmission [6]
(2) Provides the flexible network configuration [7]
(3) Assures high network life time and low equipment costs [8]
(4) Increases the reliability of the network [3].

IEEE 802.15.4 was developed in 2003 and was revised for three times in the years 2006, 2011 and 2015. The current amendment includes the features like improved data frame structures, better channel switching, enhanced frame structuring, extended superframe options, low energy operations, prioritization of channel access, enhanced acknowledgment mechanism, security [14]. IEEE 802.15.4 Network has defined fourteen Physical layer (PHY) layer standards and thirty-five Medium Access Control (MAC) functionalities. IEEE 802.15.4 network employs two kinds of devices reduced functional device (RFD) or fully functional device (FFD). RFD can only act as end node and communicates with wireless personal area network (WPAN) coordinator at regular intervals whereas FFD can be employed as WPAN coordinator, routing node, and also as a general end node [15].

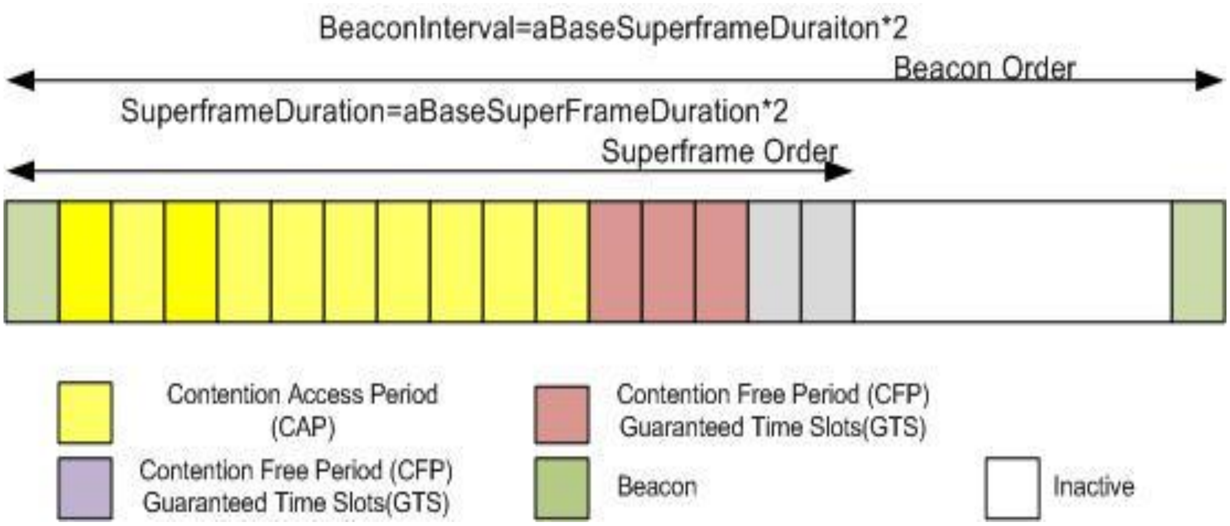

Figure 1. The Superframe architecture.

The IEEE 802.15.4 elucidates the first two layers PHY and MAC for data communication. The importance of these two layers is to set up communication among two network devices. The other two layers network (NWK) layer and application (APL) layer are defined by Zigbee alliance for establishing network topology, association, and security and encryption services [16]. The specifications of Zigbee in 2.4GHz includes the data rates of 256Kbps, with the range of 10m, can be extended up to 100m and operates at license-free ISM (2.4GHz) frequency band [17].

The superframe architecture for data packet generated from a Zigbee node is as shown in the figure 1. Contention Access Period (CAP) is the time duration where the nodes get into competition to each other so as to retrieve the channel using CSMA/CA (Carrier Sense Multiple Access/ Collision Avoidance) technique and communicates the data. Guaranteed Time slot - (GTS) is the allotted time gap for definite low latency application nodes and is allowed to conquer the channel to start transmission directly. There are total 7 slots to allow GTS broadcasts immediately after CAP. The coordinator node (cluster head) can go sleep mode and doesn't allow any data interactions among the nodes of WPAN and there shall be no beacons during this period, this type of period is generally termed as inactive period. The sum of CAP, GTS and Beacon excluding inactive period is called as Superframe Duration. The time gap between two successive beacons is termed as beacon period [18] [19].

WiFi comes under WLAN is defined under IEEE 802.11. The communication range of WiFi is up to 100m. The WiFi has a data speed of several Mb/s [20]. The WiFi node consumes more power when compared to Zigbee and hence are placed where there is a continuous supply is possible, where as Zigbee nodes operate on batteries. Hence in the coexistence environment (smart homes or smart buildings), as WiFi node is near to power supply always the link strength of the WiFi node is higher compared to Zigbee nodes [21]. As the link strength of the WiFi node is higher than the Zigbee node the data rate of Zigbee node gets influenced. Hence there is a need for research for avoiding this interference caused, to maintain the data reliability and efficiency of both the networks [22]. In the modern days the Smart buildings are deploying technologies like Zigbee, WiFi and Bluetooth for different purposes. All these technologies operate in 2.4GHz band. To maintain the reliability of each data-network application, the above technologies should not affect each other's performance [23].

The rest of the paper is structured as follows, the section 2 introduces about the related works of the IEEE 802.15.4 (Zigbee) WSN and IEEE 802.11b (WiFi). The 3rd section covers the problem identification and proposed solution. The section 4 gives the details of simulation results. The section 5 concludes the paper.

II. RELATED WORKS

Emanuele Toscano et al. [24] have provided a thorough elucidation of the MSS, aimed for defining the load scheduling capability of a Zigbee node. The performance of the Zigbee network was evaluated based on single channel or multi-channel approach while implementing an industrial WSN. Also, they have discussed in detail about implementation of the multi-channel technique. Lun-Wu Yeh et al. [25] have proposed two well-organized slot allocation algorithms depending on the theory of sequential nodes' for facilitating convergecast and broadcast traffics. It is observed as in a network if few Zigbee end devices can be re-associated to other Zigbee routers, to some extent interference may be avoided. The work in [26] has described a packet scheduling algorithm known as CoZi for Zigbee networks. The CoZi algorithm is proposed mainly to improve the bandwidth utilization of the network and reliability of the data delivery.

This algorithm mainly concentrates on the shared features of Zigbee network and is for cluster tree topology using simple network coding. This can be done for increasing the throughput and reduces transmissions by decreasing end-to-end delay.

Meng-Shiuan Pan et al. [27] have proposed a universal solution for slot allocation schemes in Zigbee networks, for improving the latency by the allocation of definite slots by reconnection of certain tree links. Explicitly, a node is allowed by the designed rules to alter a few of its neighboring nodes locally. Nodes can be allocated to a better slot to reduce the node's report latency. The work in [28] is based on node-pair classification scheme in which the risk of slot reuse can be easily accessed by a node pair. Slot reuse is disallowed when the risk is high. Slot reuse is allowed when the risk is low. This creates the need of their distributed, risk-aware, Zigbee-compatible, probabilistic beacon scheduling algorithm. Lei Tang et al. [29] have designed and evaluated the efficient multichannel MAC (EM-MAC) protocol for addressing the challenges in Zigbee. In the proposed mechanism the scheme works towards the receiver side, by assigning a channel intelligently. This work also proposed prediction based sleep and wake scheduling for a node, while resisting wireless interference and jamming.

Yoonchul Baek et al. [30] have proposed a prediction based channel scan and switch algorithm for Zigbee network to avoid WiFi interference. This scheme mainly works based on IEEE 802.15.4e standard. The Zigbee node in the network actively senses the interference from WiFi node and switched the channel based on the proposed algorithm. Min Suk Kang et al. [31] have proposed an algorithm based on adaptive interference-responsive clustering algorithm for avoiding interference in WPAN with WLAN. This clustering algorithm comprises avoidance schemes based on interference detection to adaptively reconfigure multiple channels in the network. Xi Jin et al. [32] have importantly projected a collision free superframe scheduling algorithm to find a practical solution for IEEE 802.15.4 based tree networks. Vikram et al. [33] proposes FEC-CMCMAC protocol for avoiding the interference between the channels operating in 2.4GHz ISM band and recovers the information packets lost because of collision. Firstly the algorithm estimates the delay and interference, Secondly predicts the interference based on Hidden Markov Model (HMM) based on this node shall occupy the channel with least interference. Finally forward error correction algorithm is employed for recovering the collided data.

III. PARTICLE SWARM OPTIMIZATION BASED LOAD AWARE CHANNEL ESTIMATION AND CHANNEL SCHEDULING FOR ZIGBEE NETWORKS WORKING UNDER THE INFLUENCE OF WIFI (PSOLACES)

In our previous work, a CMCMAC [7] protocol was proposed for IEEE 802.15.4 network for avoiding interference from 802.11b based nodes. In this mechanism the interference between both technologies operating in 2.4GHz band can be estimated with the help of HMM. The HMM predicts mainly based on the anticipated delay and estimated interference using Received Signal Strength Indicator (RSSI). Based on the estimation from HMM a channel with no interference effect is selected for broadcasting the data. The MAC sub-layer persists on the physical layer to minimize the Clear Channel Assessment (CCA) period and offer fairness when the estimated delay is greater than a threshold. The MAC layer triggers the channel shifting process, in selecting a better channel with minimum interference. In [33] the forward error correction was proposed as an addition to CMCMAC above so as to recover the collided data (partially lost) due to collision. Though it detects the interference proactively, the channel switching process is not proactive and hence consumes significant amount of delay.

Hence, for overcoming the above coexistence problem in 2.4GHz ISM band, the Particle Swarm Optimization based load aware channel estimation and channel scheduling for Zigbee networks under the influence of WiFi (PSOLACES) is projected in this paper. The PSOLACES algorithm is based on three schemes as shown in the figure 2. For increasing reliability of the Zigbee network working under WiFi, initially the pseudorandom based interference evading scheme is proposed. In this scheme, the node waits until network reconfiguration period after moving to the next channel based on P_{ID} and C_{ID} values. Based on the above values pseudorandom order generator (PROG) Q_{pseu} is employed for generating the sequential list of channels with low interference. Secondly, load aware channel estimation was proposed for the assessment of channel load and for evaluation of traffic weight at each channel. Finally, PSO based collision-free multichannel super frame scheduling is employed to transmit the data without any collision. The channel with best energy function is selected for data transmission.

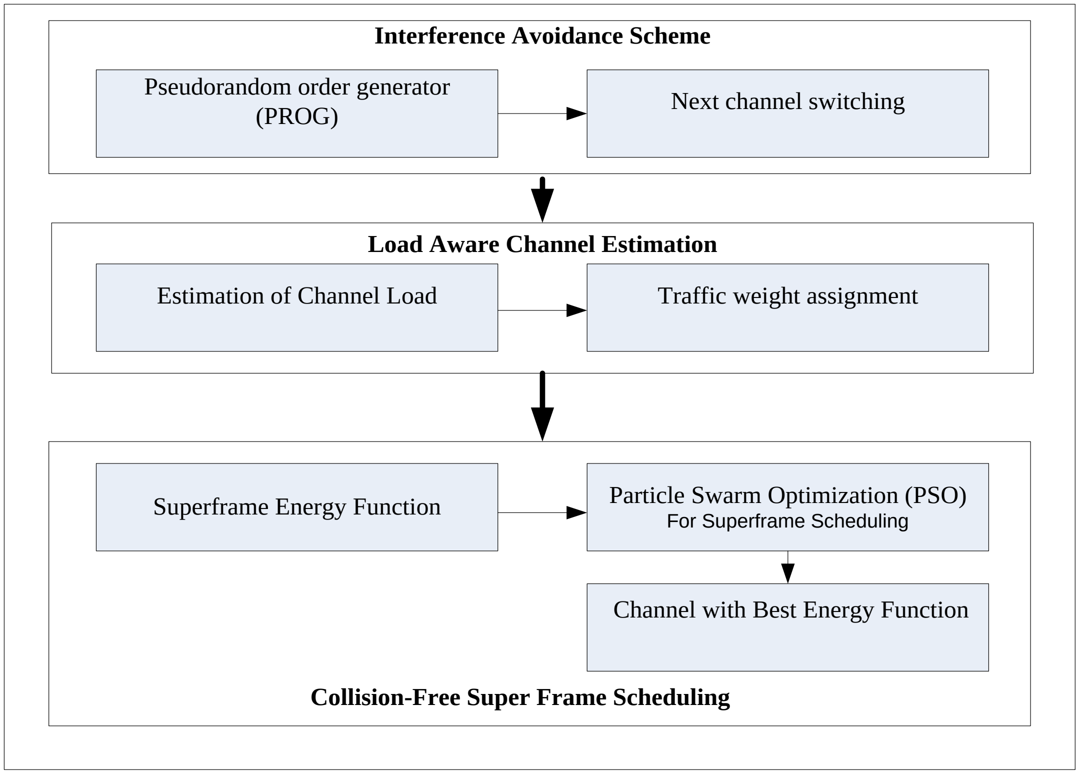

Figure 2. Block diagram of PSOLACES

a. Pseudorandom-Based Interference Evading Scheme

When an IEEE 802.15.4 based node finds interference within the same channel of 802.11b, it modifies its channel to a new channel with the help of pseudorandom-based interference evading scheme (PIE). It involves the following process, each 802.15.4 node contains some basic next channel sequence. All the nodes have a plan so as to shift to a particular channel based on the interference and availability of the channel in the network. Each node in 802.15.4 network cluster has a unique key. The format of key is as follows:

Format of Unique Key	
PAN ID (P_{Id})	Cluster ID (C_{Id})

The selection of P_{Id} of cluster head and C_{Id} of bridging devices becomes the key for the same channel group including cluster head and bridging device. Based on the unique key, each node within the group will obtain the switching sequence of channels based on the priority sequence from the PROG (Q_{pseu}). From this it can be considered as each and every node in the cluster do not have channel sequence knowledge. The figure 3, demonstrates the block diagram of PROG.

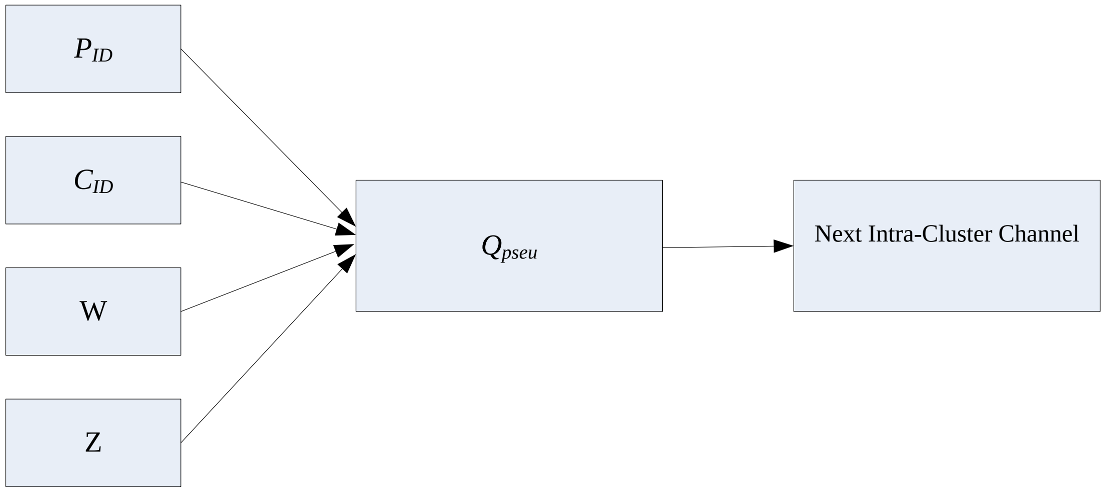

Figure 3. Pseudorandom Order Generator (PROG).

Where, W = Present Channel; Z = Counter; Q_{pseu} = PROG

The accessibility of next channel is checked before the node shifts to next channel. After an 802.15.4 node attains a channel for data communication, it is made to wait until network reconfiguration time T_{re}. The time T_{re} allows the other nodes in the network so as to move to the new channel. If the neighboring node does not identify its communication channel after T_{re} then it can be considered as, the node has failed in shifting the channel. Then all the nodes except the cluster head and PAN coordinator are detached from the network and rejoined the node again. When the node tries to re-associate again, it performs passive scan to join the network. Then node identifies the channel for the data communication in the network.

b. Load Aware Channel Estimation

b.i Estimation of Channel Load

The channel load is represented in the form of terms α and β during clear channel assessment (CCA1 and CCA2). They are anticipated at every node in the network during communication of data to the PAN coordinator. The channel busy probability α during CCA1 due to data transmission by any one of *N-1* nodes is given by

$$\alpha = S[1-(1-\chi)^{N-1}]*(1-\beta) \qquad (1)$$

Where χ is the channel sensing probability; *S* is total size of a packet;

Similarly, the channel busy probability β when CCA2 is given by

$$\beta = \frac{[1-(1-\chi)^{N-1}]+[N\chi(1-\chi)^{N-1}]}{[2-(1-\chi)^{N}]+[N\chi(1-\chi)^{N-1}]} \qquad (2)$$

These probabilities have been updated again when the node senses the channel during CCA1 and CCA2 by means of the following equations

$$\alpha_{T+1} = \gamma_b \alpha_T + (1-\gamma_b)\hat{\alpha}_T \qquad (3)$$

$$\beta_{T+1} = \gamma_b \beta_T + (1-\chi_b)\hat{\beta}_T \qquad (4)$$

Where T stand for the keep update for some value $\gamma_b \in (0, 1)$.

b. ii Traffic Weight Assignment

Each node in the network is allocated a traffic weight function so as to estimate the future acceptance data rate using the following equation

$$TW_i = \mu.R_{D(t)} + (1-\mu).R_{D(t-1)} \qquad (5)$$

Where TW_i is the traffic weight assigned to node N_i
$R_{D(t)}$ and $R_{D(t-1)}$ denote the data rate at time t and $(t-1)$ respectively.
μ is a constant.

c. iii Particle Swarm Optimization (PSO) based Load Aware Channel Estimation

The PSO defines the action of searching birds flying, by means of a communal association among themselves, forming the groups to reach optimal objective. The main inspiration for data communication from above is to facilitate the individual packets of information among the data sets so as to strengthen the network performance. In PSO system [34], a particle is an alternative feasible solution. As the numbers of particles are in coexistence to each other the kind cooperation among them obtains a best possible solution. The particles in the group self-updates by tracking the following two "extreme values": $P_{best(i)}$ value is learnt from the individual particle itself and called as the individual extreme. $G_{best(i)}$ is obtained from the present population and is called as the global optimum. After knowing the two important values, new velocity λ_i and new location ρ_i of the particle (here in this paper we consider these parameters for 802.11b) is updated as per the following equation:

$$\lambda_i(t+1) = \Omega \times \lambda_{jk}(t) + L_1 \times rand() \times [P_{best}(t) - \rho_{jk}(t)] + L_2 \times rand() \times [G_{best}(t) - \rho_{jk}(t)] \quad (6)$$

Where $\rho_{jk}(t+1) = \rho_{jk}(t) + \lambda \psi_{jk}(t+1)$

$1 \leq j \leq P$; P = number of initializes particle swarm.

$1 \leq k \leq U$; U = dimension of searching space

$1 \leq t \leq D_{\max}$; D_{max} = desired iteration of particle swarm

Ω = immobility weight

L_1, L_2 = learning factor

rand ( ) = random number in the range {0, 1}

For updating the best location of the particles and individual historical optimal position, an objective fitness function is used and a new individual and global optimal value is estimated as follows:

$$P_{best(i)}(t+1) = \begin{cases} P_{best(i)}(t), if \ (\rho_{id}(t+1) \geq P_{best(i)}(t)) \\ \rho_{id}(t+1), if \ (\rho_{id}(t+1) < P_{best(i)}(t)) \end{cases} \quad (7)$$

The right channel assignment to every node in the network is the main criteria of the proposed algorithm, the another aim is to reduce the maximum load on any channels within two-hop neighborhood of the network so PSO technique was used for load aware channel estimation and assignment.

Let $N_i = \{N_1, N_2 \ldots\ldots\ldots\ldots N_n\}$ be the static nodes.

The following steps are considered in developing PSOLACES algorithm,

Step 1

Swarm particles (SP_i) are initialized in the network. The position of the particle is randomly dispersed in space and the optimal position is estimated using this algorithm. Each SP_i represents to the nodes position and velocity (ω_i, τ_i).

Step 2

Each SP_i investigates some parameters of each node such as the traffic weight and the channel load. The fitness function $F(N_i)$ is estimated based on the channel busy probabilities using the following equation,

$$F(N_i) = \frac{1}{(\lambda_1.\alpha + \lambda_2.\beta)} \tag{8}$$

Where λ_1 and λ_2 are weighting constants.

Step 3

The global best $G_{best(i)}$ value of fitness and local best $P_{best(i)}$ position of every particle is calculated. Thus the particle includes the following information:

Position	Velocity	Local best value of fitness	Fitness
$\omega_1, \omega_2, ... \omega_n$	$\tau_1, \tau_2 \ldots \tau_n$	$P_{best\ (i)}$	F_i

Step 4

The fitness value is sorted and the first half particles containing low-fitness value move into next stage directly. Then second half-particles involve in random cross over and genetic selection.

Step 5

If the particles after crossing and adapting are better than before, then the position of $P_{best\ (i)}$ is updated with the fitness value F_i or the original location is retained.

Step 6

Update the velocity and position of each particle using Eq. (6)

Step 7

Update the position of $P_{best(i)}$ and $G_{best(i)}$ based on following condition

i) If $F_i > F_i\ (P_{best(i)})$

Then

The position of $P_{best\ (i)}$ is updated with the fitness value F_i

End if

ii) If $F_i > F_i(G_{best(i)})$

Then

The position of $G_{best\ (i)}$ is updated with fitness value F_i

End if

The value that is updated in the global best particle is said to be best and considered as best channel with least load.

Step 8

If any node N_k has greatest traffic weight, then

Selects the optimum channel with the least load

Sends the beacon

End if

Step 9

After receiving the beacon, the node updates load of the channels.

Step 10

If node not have greatest traffic weight, then

It waits for channel decision of other nodes

End if

IV. SIMULATION RESULTS

The simulator ns2.34 is utilized for the simulation of the proposed architecture. The parameters and simulation settings are presented in Table 1. The proposed PSOLACES is compared to the following techniques. Risk-Aware Distributed Beacon Scheduling (RDBS) [34] technique has proposed a beacon scheduling mechanism but has not considered the coexistence environment for WiFi. CFMSS [32] has considered superframe scheduling under the beacon scheduling process but has not considered the coexistence environment. FEC-CMCMAC [33] have considered the superframe scheduling and have recovered the data lost due to the collision but doesn’t considered the dynamic environment. FDRX [6] has considered the latency requirements as per the smart grid policies, but ignored the coexistence environment and assumed as there is no effect of interference from IEEE 802.11 on IEEE 802.15.4 based Zigbee network. The performance is evaluated mainly based on the following metrics as mentioned in the table 1.

Table 1: Simulation Settings

Nodes considered in each Scenario	20,40,60,80 and 100
Size of the Area	50 X 50m
Protocols considered	IEEE 802.15.4 & IEEE 802.11b
Routing	Zigbee Cluster Tree
Range of transmission (Zigbee)	30m
Simulation Time	50 secs – 300secs
Traffic Type considered	Constant Bit Rate (CBR) and Exponential (EXP)
Packet Size	512 Bytes
Number of Data Flows for WLAN nodes (with different data rates)	2 to 10
Antenna model	Omni Antenna
Propagation	TwoRayGround
Initial Energy (Zigbee node)	100 Joules
Receive Power (Zigbee node)	0.3 mW
Transmit Power (Zigbee node)	0.5 mW

Based on the type of the application it is very important to consider some important WSN parameters like, Packet delivery ratio (PDR), Average energy consumed, and Frame error rate (FER) for evaluating performance. The performance of PSOLACES is mainly evaluated based on the three ways. Firstly, the FER for IEEE 802.15.4 network is evaluated for different packet sizes like 20 bytes, 40 bytes and 127 bytes under the 802.11 nodes. Secondly, the number of nodes are varied from 0 - 100 i.e., the cluster size is considered based on number of nodes varied as 20, 40, 60, 80 and 100. The number of flows with different data speeds is kept constant as 6 in all the above five scenarios. Thirdly, the number of nodes is kept as constant 100 and number of flows with various data speed levels is varied from 0 – 10, i.e., 2, 4, 6, 8 and 10 flows for different WLAN speed levels are considered. The various wireless communication technologies are operating in 2.4GHz ISM frequency band. As many of them are omnipresent the coexistence issue among IEEE 802.11b and IEEE 802.15.4 nodes is unavoidable and is becoming very significant research problem for applications like Smart Grid, Home Automation etc. The figure 4 depicts Channels specification of three non-overlapping channels 1,6, and 11 of IEEE 802.11b coexisting with respect to the 16 channels of IEEE 802.15.4 (i.e., channel 11 to channel 26 of 802.15.4 operates in 2.4GHz frequency band).

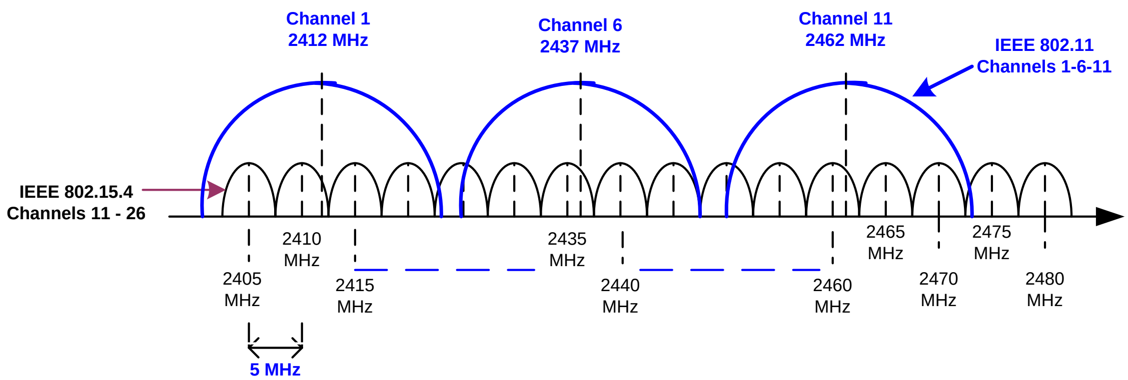

Figure 4. The 2.4GHz ISM frequency based IEEE 802.11 and IEEE 802.15.4 channels

The Frame Error Rate (FER) is estimated for coexistence environment operating in 2.4GHz ISM frequency band. Initially for estimating the FER, the network is formed by 10 nodes operating under 802.15.4 with 5meters distance a part, covering an area of 25*25 sq. meters is deployed. Among 10 devices, one device will act as Full Function Device (FFD), i.e. WPAN coordinator and other devices will act as Reduced Function devices (RFD). These 10 devices will be operated in the coexistence environment of 4 devices working based on 802.11b. The work carried studies the functioning of IEEE 802.15.4 network analyzed by employing various algorithms as above and the performance of WPAN is evaluated under the coexistence of IEEE 802.11b. The packet error rate (PER) of 802.15.4 data communication was evaluated for different packet sizes like 20bytes, 40 bytes and 127 bytes.

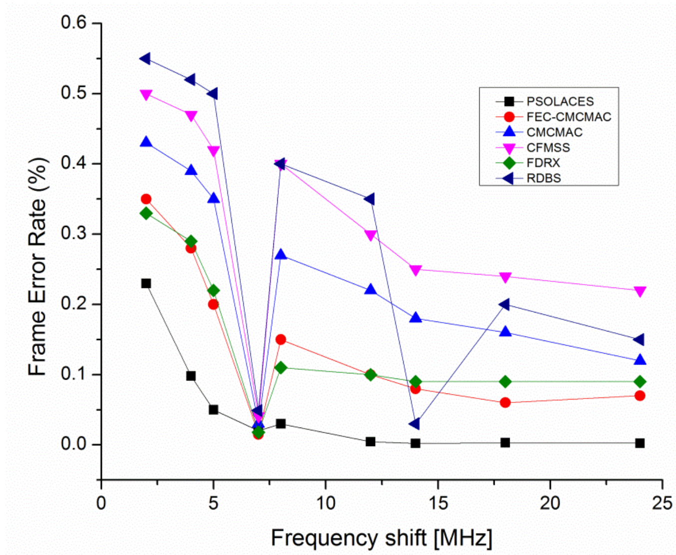

Figure. 5(a). Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 20 bytes).

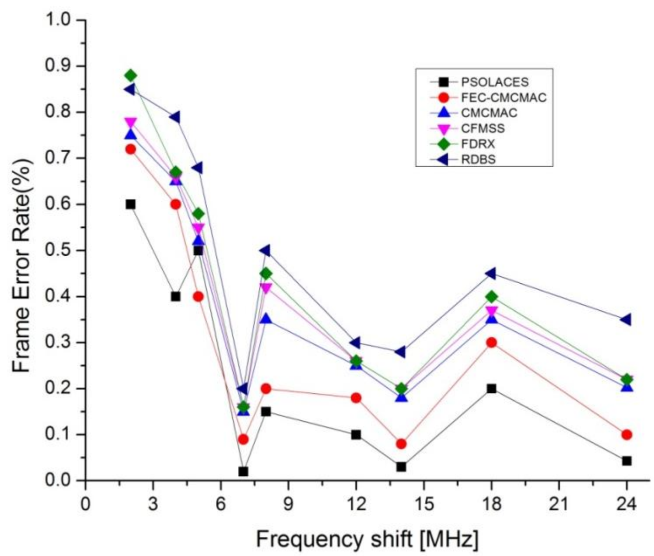

Figure 5(b). Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 40 bytes).

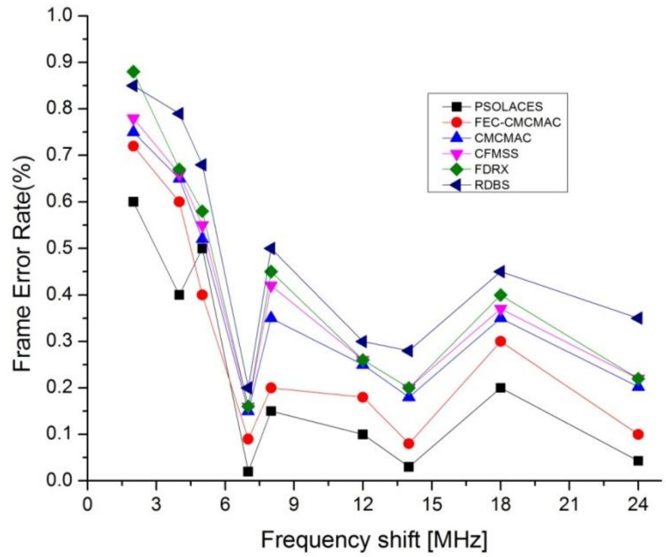

Figure. 5(c). Evaluation of FER for IEEE 802.15.4 under the coexistence of 802.11b transmission (when packet size is 127bytes).

From the graphs obtained in the figures 5(a), 5(b) and 5(c), it can be observed as, the performance of IEEE 802.15.4 based PSOLACES is performing better even under interference conditions when compared to the existing works like FEC-CMCMAC, CMCMAC, CFMSS, FDRX and RDBS. The performance of PSOLACES works best if channel shifting is made by 7MHz and works better even in the other cases too when compared to the existing. While channel scheduling, if the operational frequencies are not altered by at least above 5MHz then there is severe degradation in IEEE 802.15.4 network performance under interference. It is also inferred based on the above three graphs as, PER is increasing as the packet size is increasing but even in this case PSOLACES is performing better.

a. Varying the Number of Nodes

The number of IEEE 802.15.4 nodes in the network is varied as 20, 40, 60, 80 and 100. The above nodes are working under the influence of IEEE 80.11b nodes with, 6 different data flows as constant in all the above scenarios.

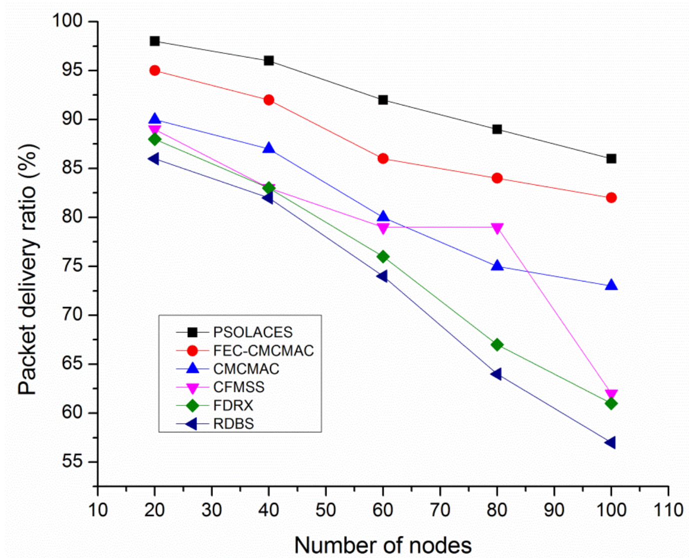

Figure. 6. Comparison of packet delivery ratio (%) by varying number of nodes.

Figure 6 illustrates the PDR (%) measured when number of nodes is varied. The IEEE 802.15.4 nodes based clusters are deployed with different cluster sizes of 20, 40, 60, 80 and 100 nodes works in coexistence with six number of IEEE 802.11b nodes simultaneously. The proposed work PSOLACES is compared with the existing works like FEC-CMCMAC, CMCMAC, CFMSS, FDRX and RDBS. The performance of PSOLACES is compared with above mentioned algorithms in terms of PDR. It is observed as PSOLACES works, 5% better when compared to FEC-CMCMAC, 11% better compared to CMCMAC, almost 13% better when compared to CFMSS, 17% better compared to FDRX and approximately 20% better when compared to RDBS.

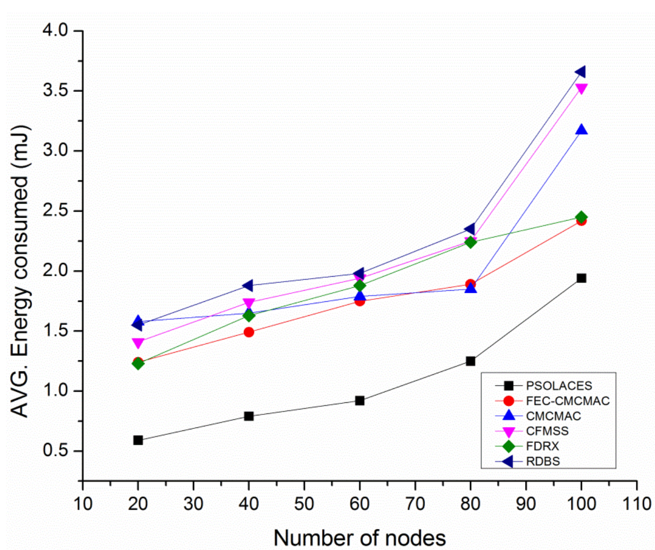

Figure. 7. Comparison of Average Energy consumed (mJ) to by varying number of nodes

Figure 7 demonstrates the Average energy consumed (mJ) when the number of nodes is varied. The IEEE 802.15.4 node based clusters are deployed with different cluster sizes of 20, 40, 60, 80 and 100 nodes works in coexistence with six number of IEEE 802.11b nodes simultaneously. The proposed work in this paper PSOLACES is compared with the existing algorithms like FEC-CMCMAC, CMCMAC, CFMSS, FDRX and RDBS. From the graph Fig.7 above it can be inferred as the Avg. energy consumed (mJ) by PSOLACES is least when compared to the other algorithms. Even at different cluster sizes also PSOLACES is working better with low energy consumption.

b. Varying the Data Flows

In this section of evaluation, the number of data flows from IEEE 801.11b nodes is varied from 2 to 10 with different data speeds for a fixed 20 number of IEEE 802.15.4 nodes.

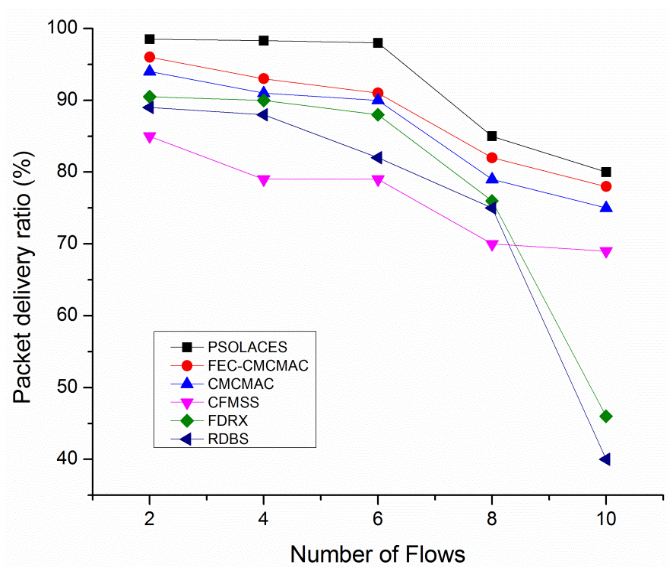

Figure. 8. Comparison of packet delivery ratio (%) by varying number of flows

Figure 8 illustrates the packet delivery ratio (%) studied when number of IEEE 802.11b based flows is varied. The IEEE 802.15.4 node based cluster is deployed with cluster size of 20 nodes works in the coexistence of IEEE 802.11b, and performance of the 802.15.4 nodes is evaluated for different data traffic flows. Initially number of flows between 802.11b nodes is taken as 2 and simultaneously flows are increased to 4, 6, 8 and 10. In this scenario the proposed work PSOLACES is compared with the existing works like FEC-CMCMAC, CMCMAC, CFMSS, FDRX and RDBS. The performance of PSOLACES is compared with above algorithms and it is observed as PSOLACES works, 3% better compared to FEC-CMCMAC, 6% better compared to CMCMAC, almost 15% better when compared to CFMSS, 14% better compared to FDRX and approximately 16% better when compared to RDBS.

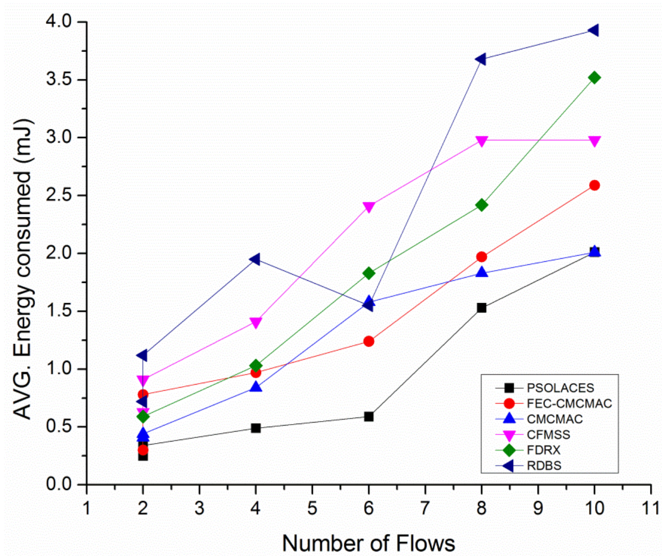

Figure. 9. Comparison of AVG. Energy consumed to the varying number of flows

Figure 9 illustrates the packet delivery ratio (%) measured when number of IEEE 802.11b based flows is varied. The IEEE 802.15.4 node based cluster is deployed with cluster size of 20 nodes works in the coexistence of IEEE 802.11b, and performance of the 802.15.4 nodes is evaluated for different data traffic flows. Initially number of flows between 802.11b nodes is taken as 2 and simultaneously flows are increased to 4, 6, 8 and 10. The proposed work in this paper PSOLACES is compared with the existing algorithms like FEC-CMCMAC, CMCMAC, CFMSS, FDRX and RDBS. From the graph Fig.9 above it can be inferred that the Avg. energy consumed (mJ) by PSOLACES is least when compared to the other algorithms. Even when 802.11b nodes based data flows are increased from 2 to 10 with different data traffic rates, even then PSOLACES performance is better and has low energy consumption when compared to others.

V. CONCLUSION

The mechanism PSOLACES technique was proposed in this paper, is based on load aware channel estimation and scheduling technique for IEEE 802.15.4 based wireless network working under the coexistence of 802.11b. In this technique, pseudorandom-based interference evading scheme is used, where the node delays up to the network reconfiguration time after moving to the next channel; hence during this delay other neighboring nodes in the network can move to the new channel. Each node's traffic weight is assigned based on its future data rate. Using PSO, the channel with least load is selected among the nodes with largest traffic weight. From the simulation results, it can be observed as the performance of PSOLACES mechanism is better when compared to the existing algorithms like FEC-CMCMAC, CMCMAC, CFMSS, FDRX, and RDBS. The comparisons were made in terms of FER estimated at different packet sizes compared to different frequency shifts, shows PSOLACES has least packet error rate and this also signify the decreased data collisions and delay when compared to other algorithms. The performance of PSOLACES was compared in terms of packet delivery ratio and energy consumed for different cluster sizes and for different data traffic flows, in all the cases the PSOLACES mechanism has shown the better performance.

The work carried is basically for improving the performance of WPAN working under IEEE 802.15.4 in the coexistence with IEEE 802.11b, keeping in the view for the applications like, modern Home Area Networks, Smart Grid scenarios and health monitoring applications. The work carried in this paper is aimed for indoor scenarios only. In the future we want to extend the work for Neighborhood Area Networks working in the outdoor scenarios operating particularly for Smart Grid networks.

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