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IEEE 802.15.4 Cluster Analysis with Different DRA & TDMA Wireless Models

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Abstract

This paper presents the IEEE 802.15.4 clustered Wireless Personal Area Network (WPAN) Sensor Network for different DRA (Dielectric Resonator Antennae) and TDMA (Time Division Multiple Access) wireless T_x / R_x models. Implementing Non-beacon enabled mode in mobile and static Zigbee nodes in the WPAN network and then analyzing: throughput, delay, load, packets sent, packets received, packets dropped etc. proved that DRA model produces enhanced performance in IEEE 802.15.4 WPAN as compared to TDMA model both for mobile and static nodes in the WPAN sensor network. The major reason is less load generated and high PDR (Packet Drop Ratio) of TDMA which leads to a smaller number of packets received and low throughput whereas DRA T_x/R_x models provides very less PDR and high load and throughput in comparison. Also, it has been simulatively proved that TDMA models do works better for static Zigbee network then mobile Zigbee network but still not equivalent or close alternative of DRA models.

1. Introduction

These Controlling Devices, Appliances and Gadgets is present as well as future such as home automation, medical data collection, embedded sensing and these concepts are easily found under Internet of things (IOT). For applying these automations, firstly we need to run these simulations on simulators. Simulation products are appropriate methods for studying and analyzing various technologies. They provide the features for the implementation of algorithms and mechanisms to study their performance, functionality and impact on a specific network under consideration. There are various simulators available in today's world. Some of them are OPNET, OMNET++, Network simulator and Matlab etc. In this research work for simulating a Wireless Sensor Network (WSN), Network Simulator (NS) has been used.

The IEEE 802.15.4 protocol implements transmission and reception layer - physical (PHY) and medium access layer Media Access Control (MAC) for communicating with other devices in the WPAN. Originally, this protocol was not implemented for WSNs, but it provided more than required flexibility to fit in to WSNs. In fact, typical requirements of WSNs are the main features of 802.15.4 protocol like: low data transfer rates, low power consumption and low cost wireless connectivity (Jurcik et al.). The lowest layer consisting of transmitter (T_x) and receiver (R_x) i.e. PHY layer is suited for WSN applications in terms of low data rates, decreased power consumption and wireless connectivity robustness. Further, MAC sub-layer in addition to providing the medium access also implements a special feature called Superframe. This MAC sublayer operates in two modes: beacon – enabled and non – beacon enabled mode. In the beacon enabled mode, Superframe is the time interval between the two given beacons which is further divided into sixteen equal time slots. Out of these sixteen time slots first and last are used for beacon generation and remaining fourteen slots are used for data transmission. While in the non – beacon enabled mode CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance) is used to access the medium by different devices in the WPAN. The main feature of the non – beacon enabled mode is the easy self – organization and scalability. But it does not provide guarantee of service as in case of beacon enabled mode. For the time critical and real time applications, implementation of beacon enabled mode is required for the generation of Superframe. The Superframe provides the feature of Guaranteed Time Slot (GTS) for providing the real time guarantee to application.

IEEE 802.15.4, because of its flexibility and suitability has attracted several recent research works. Majority of these research works have worked in the fields of evaluation or improvement of characteristics or features of the standard protocol IEEE 802.15.4 either analytically or by simulation. It makes IEEE 802.15.4 WPAN protocol "better-fit" for variety of embedded applications, industrial control systems, House Automation applications and so on in comparison to its other technology alternatives such as Bluetooth, WiFi and so on.

1.1. Literature Survey

The simulation of WNs (Wireless Networks) is explained in (Marghescu et al.) also includes IEEE 802.15.4 WPAN sensor network on Network s simulator which helped us to understand the basics of Network simulator and its working. It explains the basics of how to simulate a simple wireless network. Further IEEE 802.15.4 WPAN group consist of three devices coordinator, router and end devices. Different node densities and setups of all these three devices and their subsequent effect are briefly explained (Ameen and Nourildean S. S. Bamber and Sharma R. Silva, J. S. Silva, and Boavida). On the further evaluation IEEE 802.15.4 WPAN network performance can be studied under different topologies including star, tree and mesh. By studying all these topologies, we concluded that cluster tree topology is best to explain and create desired result as we are changing various wireless receiving (R_x) and transmitting (T_x) attributes because cluster tree topology is considered good to prolong the lifetime of the IEEE 802.15.4 WPAN sensor network as it improves energy efficiency by better utilizing the energy of the battery [4 - 7] (Ss and Bamber Khangar, Pote, and U Tembhare). On the basis of which we chose a specific cluster tree IEEE 802.15.4 WPAN network so that the result evaluation of performance Dra Power model and TDMA Power Model can be analyzed and explained. IEEE 802.15.4 network consist of two types of node setups. A mobile WSN node and a static WSN node. Mobile type consists of IEEE 802.15.4 WPAN nodes that are moving in real time whereas static type consist of IEEE 802.15.4 WPAN nodes which are fixed at station. The enhanced and optimized setups and algorithms are well explained in (Haka, Aleksieva, and Valchanov) which we utilize to create and solidify a more enhanced simulation for our scenarios. As we have obtained different simulations and results for static and mobile IEEE 802.15.4 WPAN nodes. Main objective to explore was to deal with rx/tx attributes to understand the working of different models thus providing a good base to research. In (Murata et al.) the effect on microwaves of different values of T_x / R_x attributes giving better understanding of wireless attributes which we made the basis for our research as we implemented it on IEEE 802.15.4 WPAN network.

As we are also using various power models such as IEEE 802.15.4 WPAN DRA power, DRA power no_rxstate, TDMA power models it makes power model one of the important attribute along with other node models which describes the energy consumption by a simple node to whole network is evaluated in [10 - 15] (Anastasi et al. Zhou et al.) to which we have further extended our research by pairing it along other models. By default, IEEE 802.15.4 WPAN network model uses IEEE 802.15.4 WPAN DRA power model pipeline for simulation along with all the wireless R_x/T_x attributes of DRA R_x group (in accordance to Network Simulator) which can be replaced with DRA, DRA no_rxstate, TDMA attributes or models. DRA (Dielectric Resonator Antenna) is fabricated from low loss and high dielectric constraint materials, High quality factors which help various applications for wireless devices. The DRA can operate on 2.4 Ghz used in our research as bandwidth for IEEE 802.15.4 WPAN network and can provide very good results between approximation and simulation as explored in (Aras et al.). TDMA is another R_x/T_x group that can be implemented to IEEE 802.15.4 WPAN group other than DRA R_x/T_x group. Cluster based TDMA is also an efficient scheduling mechanism, the TDMA strategy allocates slots to nodes based upon queue occupying in fractions (Balasubramanian and Anandhakumar) which can be compared with DRA R_x/T_x group uses FCFS (First Come First Service) and LNHF (Least Number number of Hops First) algorithm (Al-Harbawi et al.). Along with changing power models we also changed in noise models which a pipeline procedure capable of computing interference noise whose effects and outcome are studied in (Konings et al.) giving more clarity. We also studied the ecc model attribute that specifies the pipeline procedure for delivering the acceptability of incoming radio Transmission which needed to be studied (Guglielmo et al.) as we shifted from DRA group to TDMA group and also for working of DRA no_state group.

(Jurcik et al.) analyzes the GTS mechanism of IEEE 802.15.4 for performance evaluation. (A, M, and E) evaluates the performance of real time applications using GTS mechanism in IEEE 802.15.4 WSN cluster. (Koubaa, Cunha, and Alves) has proposed a collision-free beacon frame scheduling algorithm for synchronizing a Zigbee cluster-tree network. Authors of (Koubaa, Alves, Tovar, et al.) have evaluated the performance of IEEE 802.15.4 WPAN in slotted CSMA/CA for broadcast transmissions. (Koubaa, Alves, and Eduardo) has proposed alternative mechanisms for the implementation of the duty cycle as a function of delay bound in IEEE 802.15.4. (Chen et al.) has implemented an accurate Markov chain based analytical model for evaluating IEEE 802.15.4 performance using CSMA/CA mechanism. (C. Li, H.-B. Li, and Kohno) has investigated and improved reliability of IEEE 802.15.4 WPAN for the dropped. In (Hameed et al. Lee Zhang et al. Tao et al. Zen et al. S) authors have worked on the IEEE 802.15.4 performance investigations, evaluation and analysis. (A et al.) investigates the different parameter settings of the IEEE 802.15.4 protocol using some basic queuing strategies (FIFO and Priority Queuing) for the traffic priority. (Koubaa, Alves, and Tovar) models a WSN and also implements the minimum service guarantee to every node & a router in WPAN and also investigates the delay bounds for the data flows originating from the nodes at a given depth in the WSN and estimates the minimum resources requirements by each router. (A, Alves, and Tovar) explores the characteristics of the IEEE 802.15.4 WPAN protocol for the SNs. (G. B and H) has explored the techniques of decreasing the power consumption in WSNs. But the researchers have not so far evaluated and analyzed IEEE 802.15.4 with different DRA and TDMA models.

1.2. Problem Statement

This paper evaluates the IEEE 802.15.4 cluster tree IEEE 802.15.4 WPAN network performance for both static and mobile nodes for wireless T_x / R_x attributes of DRA T_x / R_x group and its types versus TDMA T_x / R_x group. The analysis of parameters obtained from simulations such as throughput, delay, load, traffic sent (packets per second), traffic received (packets per second) and packets dropped which gives a clear difference between the performance of IEEE 802.15.4 WPAN network under TDMA T_x / R_x and DRA T_x / R_x group.

2. System Description

By studying all these topologies, we concluded that cluster tree topology is best to explain and create desired result as we are changing various wireless receiving (R_x) and transmitting(T_x) attributes because cluster tree topology is considered good to prolong the lifetime of the IEEE 802.15.4 WPAN sensor network as it improves energy efficiency by better utilizing the energy of the battery. On the basis of which we chose a specific cluster tree IEEE 802.15.4 WPAN network so that the result evaluation of performance DRA Power model and TDMA Power Model can be analyzed and explained.

completely based on the performance of particular T_x / R_x group as beacon enabled mode would have compromised or changed general results.

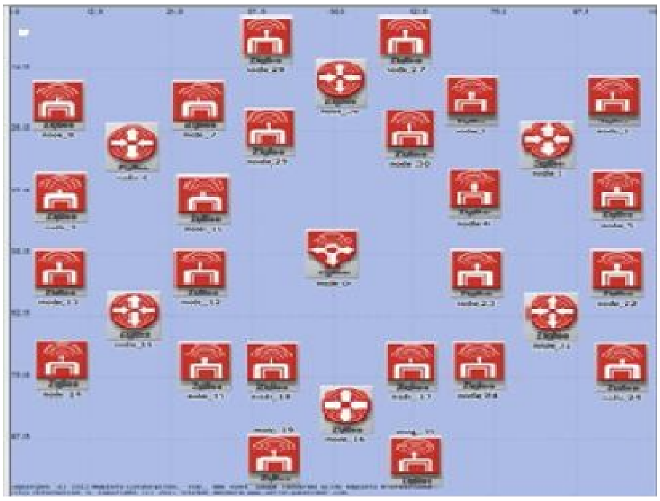

FIGURE 1. Static Node based IEEE 802.15.4 Cluster

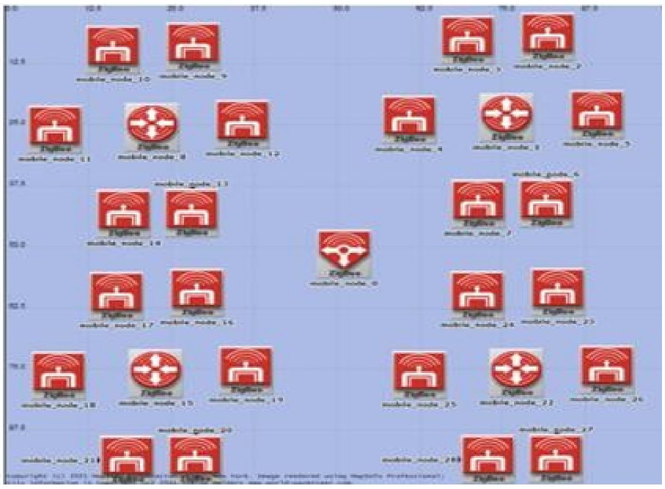

FIGURE 2. MobileNode based IEEE 802.15.4 Cluster

2.1. Experimental Settings

Network Simulator supports dynamic modeling for the wireless links between communicating nodes. The characteristic of a wireless link is that its connectivity depends on time-varying factors, such as the movement of communicating nodes, the change of transceiver properties, and interference of parallel transmission interaction.

2.1.1. Wireless T_x / R_x Attributes

Receiver Attributes (R_x): **Ragain Model** - Ragain model names the pipeline procedure that computes the antenna gain of receiver antenna for a particular incoming radio transmission.

Power Model - Power model computes received power level of the incoming radio transmissions using pipeline mechanism.

Bkgnoise Model - Bkgnoise model implements a pipeline procedure that computes the background noise affecting incoming radio transmissions.

Inoise Model - Inoise computes the interference noise affecting a particular incoming radio transmission pipeline mechanism.

SNR Model - This attribute computes signal to noise ratio for a particular incoming radio transmission using pipeline procedure.

Ecc Model - Ecc model decides the acceptability of an incoming radio transmission using a pipeline procedure.

Transmitter Attributes (Tx): **Rxgroup Model** - Model find the possibility of radio interaction between the given transmitter and receiver channel using the pipeline mechanism.

Txdel Model - Txdel model calculates the transmission delays of the packets transmitted from the source to the destination.

Chanmatch Model - This model using pipeline procedure identifies the possible outcome for characterizing the type of interaction occurring between the transmitter channel and the receiver channel.

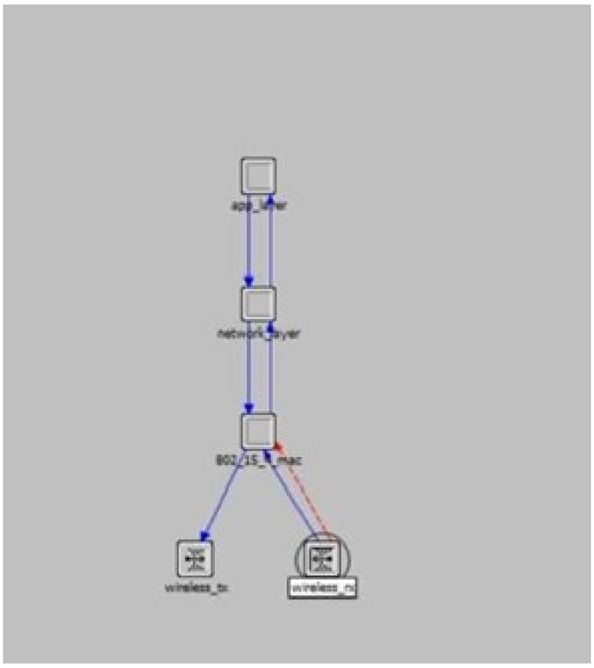

FIGURE 3. IEEE 802.15.4 Transmitter (Tx) & Receiver (Rx) Node Model

We have mainly changed power model, ecc model, inoise model, ecc model and R_x group and txdel model as only these model comes under TDMA T_x / R_x group (Figure 4).

2.2. Scenario Set Up

IEEE 802.15.4 project consists of 08 scenarios all consisting different (R_x / T_x) group setting. Main objective of the research is to study Dra vs Tdma wireless R_x / T_x group but we also considered IEEE 802.15.4 WPAN Dra (which is default power model) and Dra no_rxstate group too into consideration to check if different Dra setups produce similar or different results. Now as we are studying both for static and mobile IEEE 802.15.4 WPAN network. Our scenarios are subdivided into 2 groups as described below in the Table: 1.

3. Results and Discussions

Our result consists of overlaid graphs which are obtained by comparing Scenario (1,2,3,4) with each other which belong to mobile ZigBee network and Scenario (5,6,7,8) which belong to static 802.15.4 WPAN.

3.1. Mobile Network Scenarios

3.1.1. Throughput

Throughput: Overlaid graph of throughput for mobile network i.e. actual no of packets / frames reaching the receiver per unit time (Figure. 4)

As we can see in Figure 4 all ra groups that is Zigbee Dra, Dra and Dra_no_rxstate generate exactly same throughput nearly 114272 bits/sec confirms all dra groups works at same efficiency whereas Tdma scenario (7) generates less throughput comparatively of 25328 bits/sec. All Dra Groups have same Throughput so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma group show very less throughput.

3.1.2. Delay

As we can see all Dra groups in figure 5 that is Zigbee Dra, Dra and Dra_no_rxstate generate exactly same delay of max o.018599 bits /sec confirms all dra groups works at same efficiency whereas TDMA scenario (3) generates little less delay of 0.18348 bits/sec comparatively. All Dra Groups have same delay so only single curve is generated for scenario (1,2,4) whereas it is clearly seen in scenario (3) that Tdma group shows little less delay which is small advantage over Dra group.

Overlaid graph of Load for mobile network (Figure 5). As we can see from figure 5 that all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate generate exactly same load of 33073 bits/sec confirms all dra groups works at almost identically whereas TDMA scenario (3) generates load 6896 bits /sec which is very less comparatively. As all Dra Groups have same Load so only single curve is generated for scenario (1,2,4) whereas it is clearly seen in scenario (3) that Tdma group show very less load.

3.1.3. Traffic Sent

Overlaid graph of Traffic sent for mobile network (Figure 7). As we can see all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate sent exactly same number of packets 14 packets/sec confirm all dra groups works identically whereas tdma scenario (3) sent less than half the packets comparatively which are 6 packets /sec. All Dra Groups have same number of packets sent so only single curve is generated for scenario (1,2,4) whereas it is clearly seen in scenario (3) that Tdma group show very less packets sent ratio.

3.1.4. Traffic Received

Overlaid graph of traffic received in mobile network (Figure 8). From the Figure 7, it is clear all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate receives exactly same number of packets which are 14 packets/sec confirming all dra groups works identically whereas Tdma scenario (3) receives very a smaller number of packets 3 packets /sec comparatively because packets sent were less as seen in traffic sent. All Dra Groups have same Traffic received so only single curve is generated for scenario (1,2,4) whereas it is clearly seen in scenario (3) that Tdma receives very less packets comparatively.

3.1.5. Packets Dropped

Overlaid graph of packets dropped for mobile network (Figure 9)

As we can see all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate packet drop ratio is very less 540 bits/sec confirms all dra groups works identically whereas Tdma scenario (3) drop ratio is very high which is 936 bits/sec which explain why a smaller number of traffic received, also explains why load and throughput are less thus taking less delay time. As we can see all Dra

3.2. Static Network Scenarios

TABLE 1. IEEE 802.15.4 Scenarios

Scenarios	Rx/Tx Group	Description
Mobile Network Scenarios		
Scenario-1	Zigbee Power model along with dra rx/tx attributes	Keeping the default parameters same as before in wireless tx attributes. By default IEEE.802.15.4 WPAN uses dra power model with other models of dra rx/tx group.
Scenario-2	dra power model along with dra(rx/tx) attributes	Zigbee dra power and dra power have all attributes same other than just power model hence keeping all tx attributes as default. Changing power model from zigbee dra power to dra power only in wirless rx attributes.
Scenario-3	Tdma	Changing rx group model to tdma rx group and changing txdel model to tdma txdel in wireless tx attributes. Changing Power model to tdma_power, inoise model to tdma_inoise and ecc model to tdma_ecc model in wireless rx attributes.
Scenario-4	dra_no_rxstate model along with dra no_rxstate (rx/tx) attributes	Changing rx group model to dra_rxgroup_no_rxstate in wirless tx attributes. Changing Power model to dra_power_no_rxstate and ecc model to dra_ecc_no_rxstate in wireless rx
Static Network Scenarios		
Scenario-5	Zigbee Power model along with dra rx/tx attributes	Keeping the default parameters same as before in wireless tx attributes.By default IEEE802.15.4 uses dra power model with other models of dra rx/tx
Scenario-6	dra power model along with dra(rx/tx) attributes	zigbee dra power and dra power have all attributes same other than just power model hence keeping all tx attributes as default. Changing power
Scenario-7	Tdma	Changing rx group model to tdma rx group and changing txdel model to tdma txdel in wireless tx attributes. Changing Power model to tdma_power, inoise model to tdma_inoise and ecc model to tdma_ecc model in wireless rx attributes
Scenario-8	dra_no_rxstate model along with dra no_rxstate (rx/tx) attributes	Changing rx group model to dra_rxgroup_no_rxstate in wirless tx attributes. Changing Power model to dra_power_no_rxstate and ecc model to dra_ecc_no_rxstate in wireless rx attributes

3.2.1. Throughput

Overlaid graph of throughput for static network (Figure 10). As we can see all Dra groups that is Zigbee Dra, Dra generate exactly same throughput of 222462 bits/sec whereas Tdma scenario (7) generates less throughput 80296 bits/sec comparatively. All Dra Groups have same Throughput so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma group show very less throughput but more than that in mobile scenario.

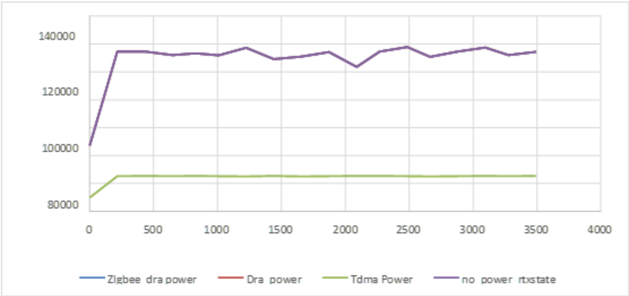

FIGURE 4. **Throughput in Mobile Networks**

3.2.2. Delay

Overlaid graph of Delay for static networks (Figure 11).

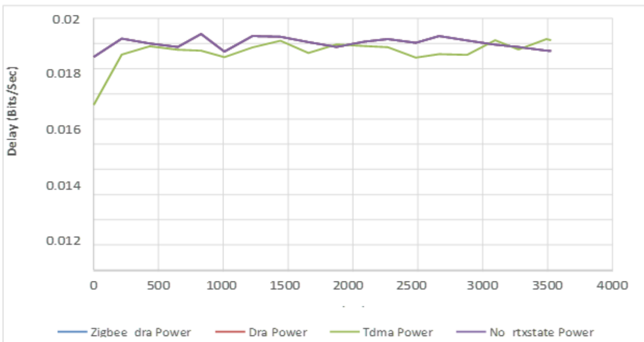

FIGURE 5. **Delay for Mobile networks**

As we can gain from graph all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate generate exactly same delay of max 0.02589 bits /sec confirms all dra groups works at same efficiency whereas Tdma scenario (7) generates little less delay of avg 0.016049 bits /sec comparatively. As all Dra Groups have same delay so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma group shows little less delay which is small advantage over Dra group.

3.2.3. Network Load

Overlaid graph of Load in static networks (Figure 12)

As we can see in figure 12 that all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate generate exactly same load of 50344.44 bits/sec confirms all dra groups works at almost identically whereas Tdma scenario (7) generates less load of avg 20640 bits/sec comparatively. All Dra Groups have same load so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma group show very less load comparatively.

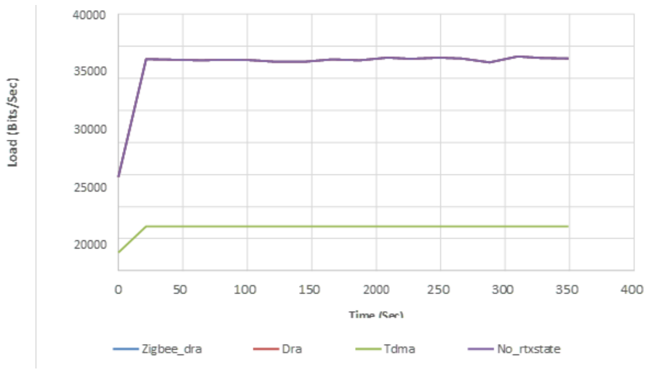

FIGURE 6. **Load in Mobile Networks**

3.2.4. Traffic Received

Overlaid graph of Traffic received for static network (Figure 14). As we can see all Dra groups that is ZIGBEE Dra, Dra and Dra_no_rxstate recieves exactly same number of packets that is 24.19 packets /sec confirms all dra groups works identically whereas Tdma scenario (7) receives very a smaller number of packets comparatively 11 packets/sec because packets sent were less as seen in traffic sent. All Dra Groups have same number of packets sent so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma receives very less packets comparatively.

Overlaid graph for traffic sent in static scenario (Figure 13). As we can see in graph all Dra groups that is ZIGBEE Dra, Dra and Dra_no_rxstate sent exactly same number of packets which are 21 packets/sec confirm all dra groups works identically whereas tdma scenario (7) sent packets comparatively which are 14 packets/sec. All Dra Groups have same number of packets sent so only single curve is generated for scenario (5,6,8) whereas it is clearly seen in scenario (7) that Tdma group show very less packets sent ratio.

3.2.5. Packets Dropped

Overlaid graph of Packets dropped for static network (Figure 15).

As we can see all Dra groups that is Zigbee Dra, Dra and Dra_no_rxstate packet drop ratio is very less 540 bits/sec confirms all dra groups works identically whereas Tdma scenario (3) drop ratio is very

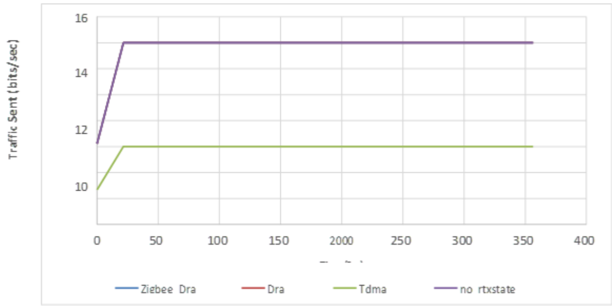

FIGURE 7. Traffic Sent in Mobile Networks

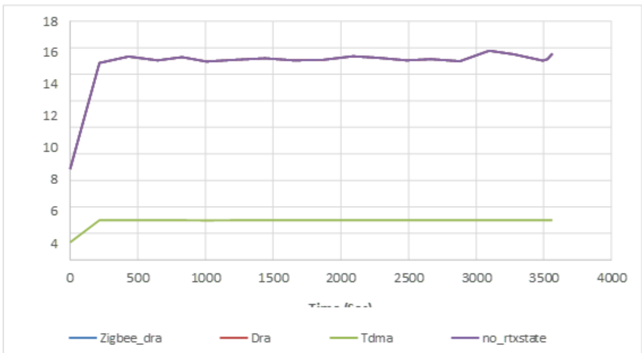

FIGURE 8. Traffic Received in Mobile Networks

high which is 936 bits/sec which explain why a smaller number of traffic received, taking delay less time. As we can see all Dra also explains why load and throughput are less thus groups that is Zigbee Dra, Dra and Dra_no_rxstate drop ratio is very less confirms all dra groups works identically whereas Tdma scenario (3) drop ratio is very high which explain

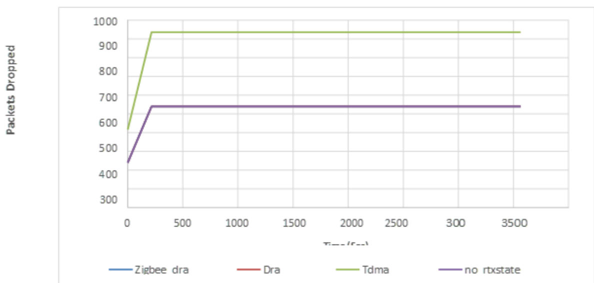

FIGURE 9. Packets Dropped in MobileNetworks

4. Conclusion

Simulations using NS simulator for the IEEE 802.15.4 frame structure Cluster Tree Zigbee Network on the basis of comparison of different DRA and TDMA wireless R_x / T_x models have been carried out. Using non-beacon enabled state in mobile

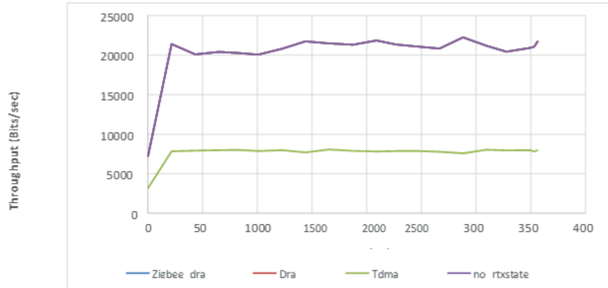

FIGURE 10. Throughput in StaticNetworks

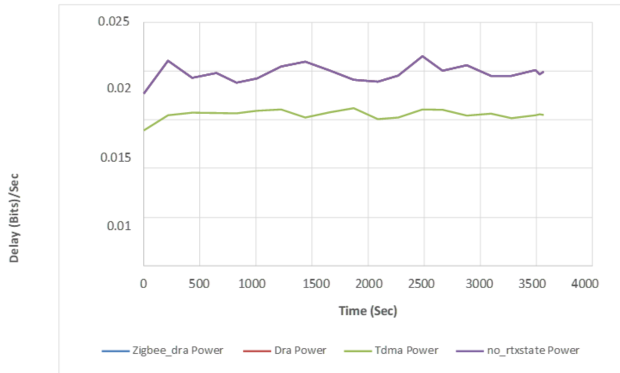

FIGURE 11. Delay in Static Networks

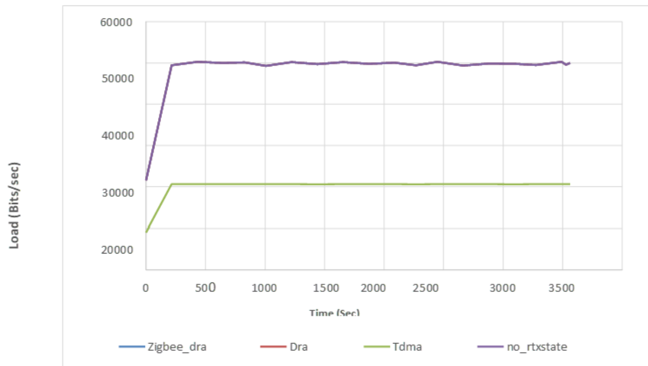

FIGURE 12. Load in Static Networks

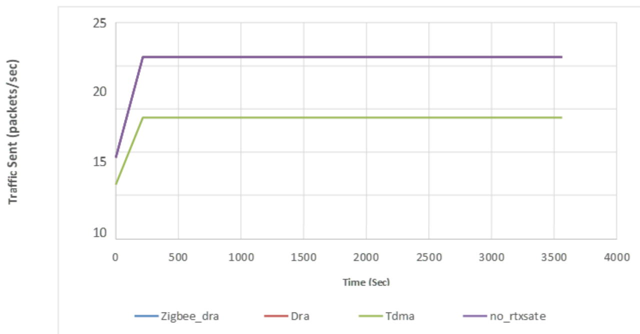

FIGURE 13. Traffic Sent in StaticNetworks

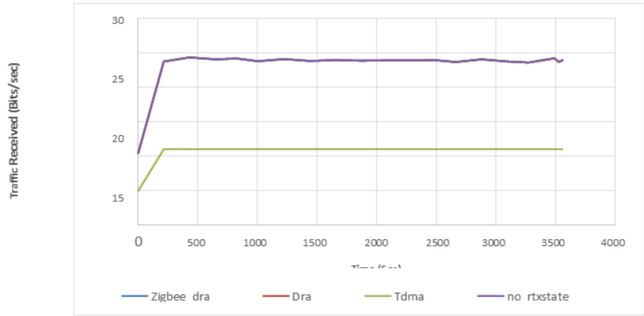

FIGURE 14. **Traffic Received in StaticNetworks**

FIGURE 15. **Packets Dropped in StaticNetworks**

and static Zigbee network and analyzing Throughput, Delay, Load, Packets sent, received and dropped ratio to understand which rxgroup is more affective and reason behind it.

After detailed analysis and simulation results obtained, it is concluded that DRA R_x / T_x group is more effective than TDMA group for both static and mobile WPAN network. Although cluster based TDMA is an efficient strategy to use but still it is less effective as compare to DRA R_x / T_x group models when it comes to wireless networks specifically (LR-WPAN). The major reason is less load generated and high PDR (packet drop ratio) of TDMA which leads to a smaller number of packets received and low throughput whereas DRA R_x / T_x models provides very less PDR and high load and throughput in comparison, which further explain why IEEE.802.15.4 WPAN uses DRA attributes as default.

Further it is concluded from results that TDMA do works better for static Zigbee network then mobile Zigbee network but still not equivalent or close alternative of dra models. Hence DRA R_x / T_x models are better than TDMA R_x / T_x models is proved. Also, it is concluded that no rx group other than TDMA can be used in IEEE 802.15.4 networks.

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