Performance Analysis of LAR and DYMO Protocol in GTS Mechanism Enabled IEEE 802.15.4 Based Wireless Sensor Networks

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Abstract
Recently, there is a rapid development in Wireless Sensor Network (WSN) which motivates the research on ZigBee networks. The motivation is due to low power, date rate and small size sensor nodes. It has started to emerge as the next generation wireless standard for Low-Rate Wireless Personal Area Networks (LR-WPAN). IEEE 802.15.4 is the standard specified for LR-WPAN. IEEE and ZigBee alliance have joined hands to develop a complete specification of protocol stack for 802.15.4. The Guaranteed Time Slot (GTS) mechanism provided by IEEE 802.15.4 standard allocates specific time slots to all nodes in the network and makes communication more consistent. This consistency makes the network to enhance their performance. The work in this paper focuses on the performance analysis of routing protocolsin GTSmechanism enabled IEEE 802.15.4 based wireless sensor networks. Performance metrics such as packet delivery ratio, delay, jitter and packets dropped of IEEE 802.15.4 based wireless sensor networks are analysed using Location Aided Routing (LAR) protocol. It is then compared with that of DYnamic MANET On-Demanding routing protocol (DYMO) for performance evaluation.

Keywords
Wireless Sensor Network, ZigBee, IEEE 802.15.4 standard, Guaranteed Time Slot, LAR

I. Introduction

Many new applications and distributed systems have been revolutionized by LR-WPAN in recent years. The IEEE 802.15.4 based ZigBee standard is a widely used LR-WPAN. The successful release of the IEEE 802.15.4 standard offers a great convenience to applications of low power and low-rate wireless sensor networks which almost overcomes all aspects of communication [1]. Numerous applications have been facilitated by Zigbee networks such as consumer electronics, health and medical monitoring, home automation and battlefield monitoring. It also supports simple devices that consume minimal power and operate in the Personal Operating space (POS) [2] and version of this standard is fully compatible with IEEE 802.15.4. It consists of simple design regarding interoperability, long battery life scheme and maintaining simple and flexible protocol stack [3].

ZigBee devices are mainly categorized into Full Function Device (FFD) and Reduced Function Device (RFD). The FFD can function as a Personal Area Network (PAN) coordinator or coordinator. It can communicate with either another FFD or a RFD. The RFD can be used in simple applications in which they do not need to transmit large amounts of data and instead they have to communicate only with a specific FFD.

The star, tree and peer-to-peer network topologies are defined for ZigBee at network layer and provide a framework for ZigBee application in the application layer. In star topology communication is established between devices and Personal Area Network (PAN) coordinators. It takes control of all devices in the network. Each star network chooses PAN coordinator with PAN identifier and creates a personalized star network. In tree topology majority of the devices are FFD. It may communicate with any node or rejoin the network. Any FFD device in a network can act as coordinator and provide synchronization to other devices in the network. In peer to peer network, all devices can establish connection to communicate each other provided they are within the range. This network is initialized with one PAN coordinator and allows to route multihop messages to all devices in that particular network. The advantage of this topology is reliability, self-organizing and self-healing [4].

This paper evaluates the performance of LAR and DYMO protocol in GTS mechanism enabled wireless sensor networks. The rest of the paper is structured as follows. Section 2 deals with overview of GTS mechanism enabled IEEE 802.15.4 standard. Section 3 describes the routing protocol in detail. Section 4 emphasises the QualNet simulation scenario and the analysis of the simulation result. Section 6 concludes the paper with conclusion and future scope.

II. Overview of ieee 802.15.4 standard and gts mechanism

ZigBee specification has been proposed on IEEE 802.15.4 based LR-WPAN [5]. The advantages of this standard are easy deployment, short range transmission, reliability, low cost, simple and flexible protocol stack for interoperability. It has been developed on the Physical Layer (PHY) and Medium Access Control (MAC) sublayer for LR-WPANs. Three frequency bands are supported by the physical layer. An 868 MHz band with 1 channel and 915 MHz band with 10 channels relay on Binary Phase Shift Keying (BPSK) modulation technique. The first and second frequency band offers 20and 40 Kbps respectively. A 2450 MHz band with 16 channels employing Offset Quadrature Phase Shift Keying (O-QPSK) offers a data rate of 250Kbps.The physical layer also ropes the functionality of channel selection, Link Quality Indication (LQI), energy model management and Clear Channel Assessment (CCA) [6].

The MAC layer of IEEE 802.15.4 standard employs two modes of operation namely beacon enabled and nonbeacon enabled node. In nonbeacon enabled mode, nodes are not synchronized due to absence of periodic beacons. Unslotted CSMA/CA mechanism facilitates this mode for communication among nodes. This mode requires robust power to make the devices to be in active. The beacon enabled mode is characterized by periodic transmission and synchronization of beacon messages [7]. This mode operates in slotted CSMA/CA and depends on data rate. The nature of time evolution is the major difference between slotted and unslotted CSMA/CA mechanism. Periodic beacons confirm the presence of node and may sleep between beacons thus extend the battery

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life and lower the duty cycle.

The beacon enabled mode also supports GTS mechanism. The GTS allows a specific node to use the channel exclusively for a given time slot. It ensures and guarantees communication with PAN coordinator. Hence,PAN coordinator relays on GTS based communicationto transmit time sensitive and important data. GTS allocates time slots for PAN coordinator. The device transmits beacon frame immediately without processing delay. Beacon Interval (BI) identifies PAN coordinator by beacon frames transmitted by the corresponding FFD.

The frame format shown in figure 1 explains super frame structure. It comprises of active and inactive period. The active period are sized into 16 equal time slots. It is equivalent to Superframe Duration (SD) used for transmission and does not exceed BI. The active period is further classified into Contention Access Period (CAP) and Contention Free Period (CFP). The CFP incorporated with GTS scheme uses slotted CSMA/CA mechanism [8].Figure 2 illustrates GTS mechanism in IEEE 802.15.4 standard. GTS enabled device requests a GTS allocation command frame to PAN coordinator. It is encapsulated in CAP for communication process. After receiving GTS request, PAN coordinator allocates GTS request only when sufficient GTS slots are accessible.

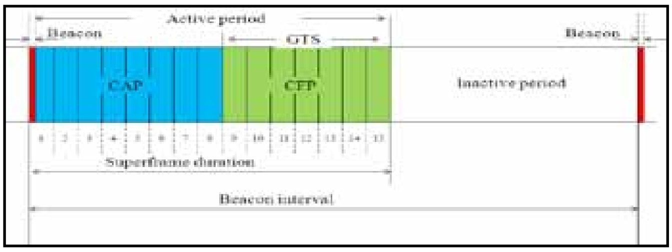

Fig. 1 : Frame Format of superframe structure

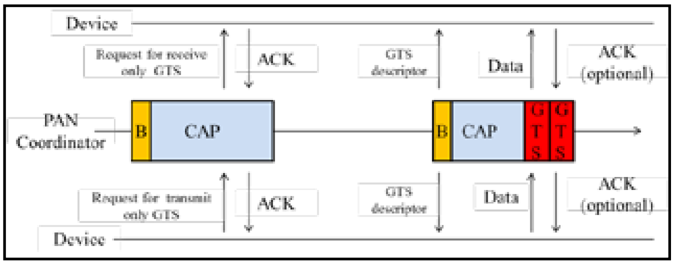

Fig. 2 : GTS mechanism in IEEE 802.15.4 standard

It generates a GTS descriptor with short address of the device along with requested specification [9]. After successful allocation of GTS, PAN coordinator sets the GTS descriptor and superframe slot to initiate the GTS mechanism. At this stage, length of GTS descriptor equals length of GTS. If the GTS slots are not available, the initiating slot is set to 0 and the length with largest GTS is supported.The PAN coordinator encloses GTS descriptor in beacon and updated the GTS specification of beacon frame. A device receives a beacon frame enclosing GTS descriptor corresponds to the MACshort address of the device [10]. A MACshortaddress is a 16-bit address used by the devices to communicate in the PAN coordinator. If the device is PAN coordinator the macshortaddress can be chosen before the initialization of PAN in the network. Otherwise the MACshortaddress is allocated by a coordinator during network association. The success and failure of the GTS allocation is confirmed by setting start id to 0. In exceptional cases, GTS can utilize CAP for communicating with the other devices in the network.

III. Routing Protocols

Routing protocols of IEEE 802.15.4 based wireless sensor networks are broadly classified into proactive, reactive and geographical routing protocols. Proactive protocols are those that depend on routing table maintained by each node in the network. It updates the routing table and information periodically as network topology changes over time. Since a proactive protocol has to maintain node entry for every node, this protocol is not applicable for large network. Protocols that perform route discovery only when source needs to transmit data to destination and these protocols are called reactive protocols. Routing tables are not maintained by these types of protocols. Protocols are also classified based on the position in the network. These types of protocols are also called as geographic routing protocols because it relies on the geographic position information of node. The advantage of this protocol is that it can transmit data to the destination inspite of using network address. This section deals with the description of two widely used protocols.

A. DYnamic MANET On-Demanding routing protocol (DYMO)

It is a reactive routing protocol constructed upon the configuration of AODV. The routes are updated and ensured with the sequence number. This feature standardizes the route discovery messages in DYMO protocol. It uses path accumulation mechanism in which a node will receive all information about the intermediate nodes of a new route in addition to route information about a requested destination.

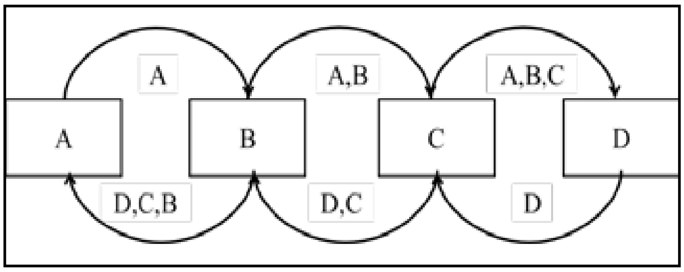

Fig. 3 : Routing mechanisms in DYMO

This is the key difference of DYMO from other routing protocol. Figure 3 shows the routing mechanism of DYMO protocol. It produces routing table entries for destination node and stores routes for all intermediate hops. It discards the old packet and routes the buffered data packet. Route discovery is accompanied by locating the routing table. The nodes transmit a Route REQest (RREQ) to all nodes only when a valid route does not exist in the network. When an intermediate node receives a RREQ, it records the appended information of route to all nodes passed through, updates information about itself and accumulates it to neighboring nodes. DYMO performs route maintenance when there is route failure or when route becomes unavailable [11]. The maintenance node generates a Route ERRor (RERR) packet. It encloses list of all entries in routing table that is dependent on route failure or unavailable node. The RERR message is also transmitted to all nodes.

B. Location aided routing

It is a protocol which executes route discovery through directional flooding by locating the position of every node in the network. Figure 4 illustrates the routing in LAR protocol. If a source node S needs to find a route to destination node D, node S must broadcasts

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a route request to all its neighbors. X receives a route request from the intermediate node and compares the destination with its own identity. If it does not match, then node X broadcast the request to its neighbors with sequence numbers used to detect duplicate and eliminate redundant transmissions. Node D responds by route reply messages to sender which traverse the path in reverse of the path received by D (route request packet contains path of all nodes traversed starting S).

If any transmission error or node D is unreachable, timeout scheme is used to re-initiate route request with new sequence number. However in proactive protocol, routing depends on table which is constructed with respect to source. Hence number of hops is increased in proactive routing protocols. But in LAR protocol routing is done with respect to destination node. So hops are reduced in LAR [12]. Two different schemes are proposed in LAR. The first scheme uses a request which defines a boundary where route request packets can travel to reach the required destination. The second method identifies coordinates of the destination in route request packets [13].

These packets can only travels in the direction where the relative distance to the destination becomes smaller as they travel from one hop to another. Both methods limit the control overhead transmitted through the network and hence it conserves the bandwidth. It also determines the shortest path (in most cases) to the destination, since the route request packets travel away from the source and towards the destination. The main disadvantage of this protocol is that each node carries GPS information [14]. The other disadvantage is that LAR protocol leads to more congestion for more dynamic type of networks.

IV. Simulation result

The simulation scenario models the performance comparison of LAR and DYMO protocol in GTS Mechanism enabled Wireless sensor Networks. This section describes the performance metrics and the parameters used in the simulation.

The simulation is performed using QualNet network simulator version 6.1. A comprehensive tool for modeling wireless sensor network is QualNet. It offers different simulation parameters that can be configured for various layers in network. QualNet analyser provides statistics for each level of network as per interconnection model [15]. This work focuses on performance parameters like packet delivery ratio (PDR), delay, jitter and packets dropped in network. The simulation is executed for network size of 100 x100 m2 with various node densities from 50 to 100 nodes. All nodes in the network are deployed randomly by node placement option.

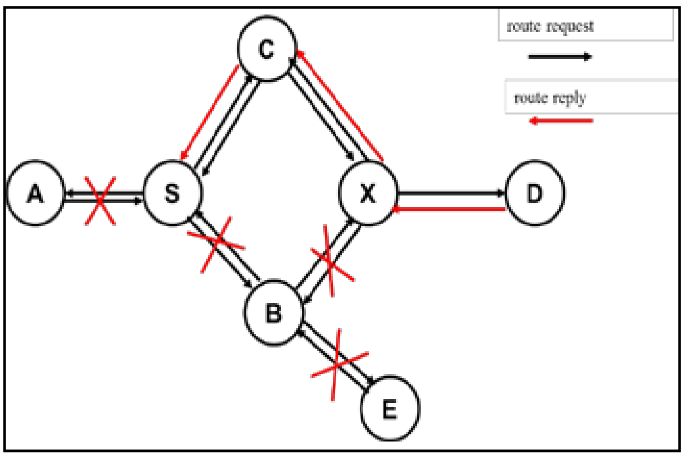

Fig. 4 : Illustration of route discovery by Flooding

Table 1: Simulation Parameters

Parameters	Values
ZigBee frequency band	2.4GHz
Data rate	250Kbps
Modulation	O-QPSK
Simulation time	300sec
Battery model	Simple Linear, 20mAhr
Transmission power	3dBm
Protocol	Location Aided Routing
Network Area	100x100 m^2
No. of nodes	50, 60, 70, 80, 90, 100
Energy Model	MicaZ
Topology	Cluster Tree
Packet size	60 bytes
Traffic Application	ZigBee

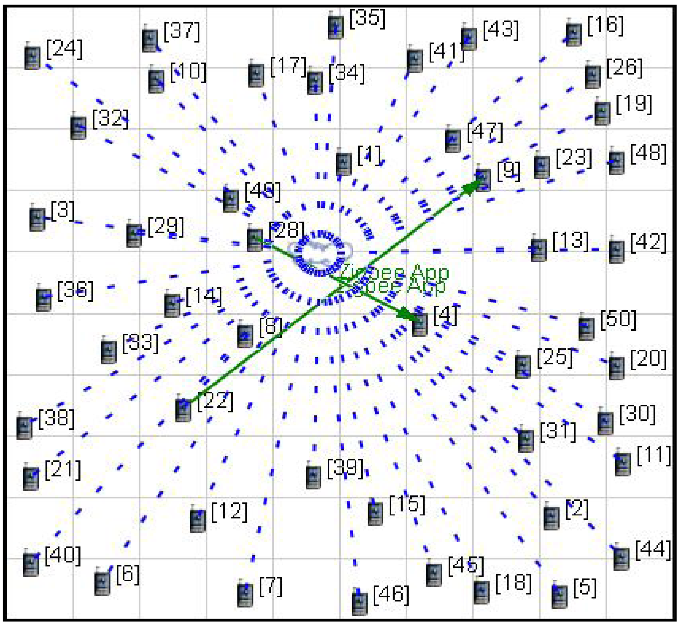

Fig. 5 : QualNet visualization scenario for 50 nodes with 100 x100 m^2

It uses ZigBee traffic application for communication with a packet size of 60 bytes. Table 1 outlines the simulation parameter. QualNet visualization environment for 50 nodes is emphasized in Figure 5. Node 22 and 28are transmitting node whereas 9 and 4 are receiving node. The transmitting nodes and routers are configured as FFD and other devices are configured as RFD.Analysis of Packet Delivery Ratio

C. Analysis of Packet delivery ratio

Packet delivery ratio (PDR) is defined as the ratio of total number of packets received to number of packets transmitted in the network. Figure 6 portrays average packet delivery ratio for varying node densities. For network with low node density, namely 50 and 60, probability of route failures is low. In DYMO, route is discovered quickly with the help of path accumulation scheme for reduced node density. It effectively

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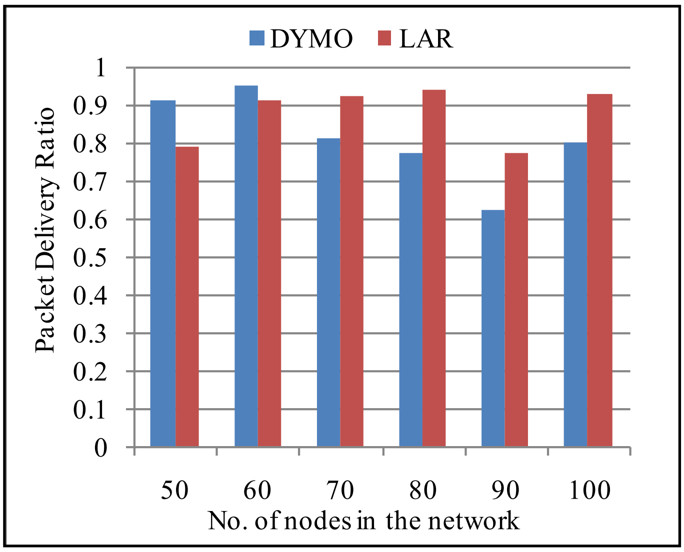

Fig. 6 : Performance comparison of packet delivery ratio of DYMO and LAR

reduces the packet loss. This results in a higher packet delivery ratio in DYMO for lower node density. However, DYMO has lower packet delivery ratio for increased node density.The reason is that probability of route failure is more for increased node density in DYMO protocol which inturn increases the packet loss. For LAR protocol the position of nodes must be considered for routing along with shortest path. LAR protocol offers higher packet delivery ratio for increased node density . This is due to presence of random backoffs,collision avoidance and less packet loss achieved by LAR for higher node density network . Hence, LAR outperforms DYMO especially for networks with larger numbers of nodes that is verifed through the simulation result.

D. Analysis of Delay

Figure 7 illustrates delay for varying node densities. Delay refers to the time taken for a packet to be transmitted across a network from source to application layer of destination. In LAR protocol, delay is higher for lesser node densities namely 50 and 60 nodes. It takes more time duration for transmitting data from source to destination for reduced node density in the network for LAR protocol. As DYMO uses path accumulation mechanism it can reach the destination node rapidly.

The disadvantage of DYMO is its difficulty in upgrading the nodes with path accumulation mechanism for the network with large node density. For network with large node density, LAR outperforms DYMO in terms of delay. The reason is due to the transmission of data from source to destination by choosing the shortest routealong with the position of the destination node and with fewer hops which in turn reduces delay.

E. Analysis of Jitter

Figure 8 depicts jitter for varying node densities. Jitter refers to variation in delay of received packets even if they are sent at same time. For network with small node densities namely 50 and 60jitter is reduced as DYMO uses path acuumalation mechanism. The path identification for LAR protocol is inconsistent which increases jitter for the network with lower node density. LAR performs better than DYMO for networks with increased node densities.As number of nodes in the network increases, LAR protocol tends to have path identification consistentlywhich inturn decreases the jitter. But, DYMO has to update path for each and every node in the network with increased node density. It incurs more delay for large node density resulting in increased jitter.

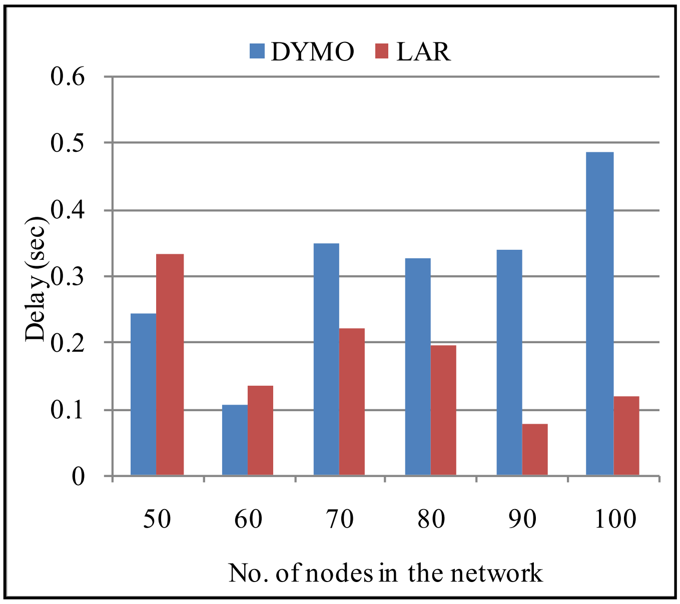

Fig. 7 : Performance comparison of Variation in delay with network density

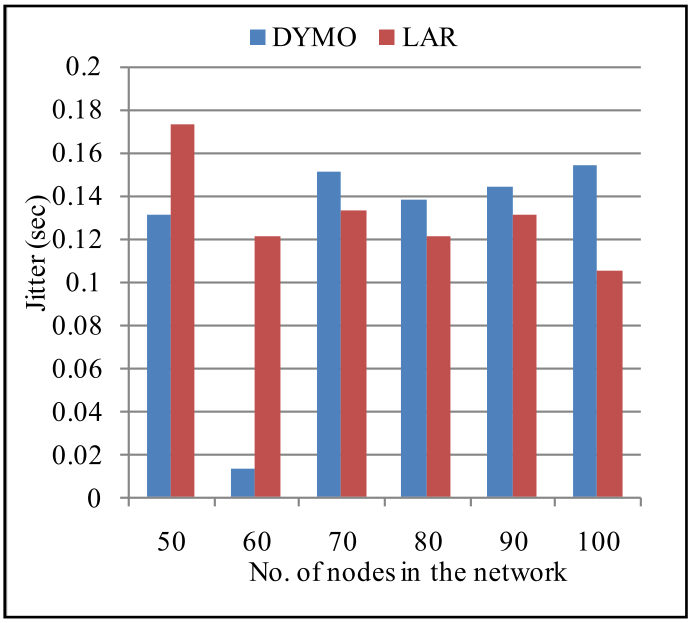

Fig. 8 : Performance comparison of jitter

F. Analysis of Packets Dropped in the network

Figure 9 shows the variation in the packets dropped for various node densities. From the simulation results, it is observed that LAR out performs DYMO for the network with increased node density.

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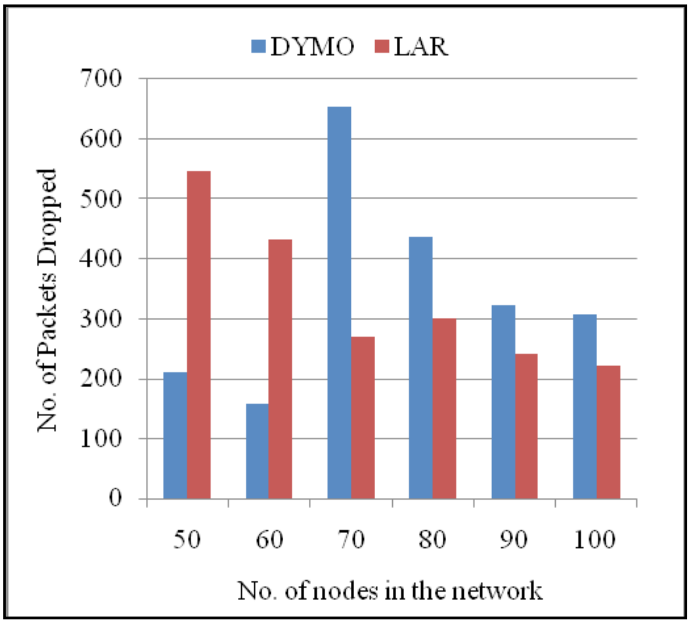

Fig. 9 : Performance comparison of packets dropped in the network

As number of nodes decrease in the networks, DYMO outperforms LAR. DYMO being a reactive protocol, better path accumulation mechanism can be maintained for smaller nodes densities. But, route discovery in large node densities is consistent in LAR protocol. So packets dropped are low for LAR protocol in the network with increased node densities. However, route discovery is not reliable for smaller node densities and packed dropped is more in small node densities for LAR protocol.

V. Conclusion and Future Scope

Several research works have been carried out on different types of routing protocols for IEEE 802.15.4 based wireless sensor networks. This paper models the performance comparison of LAR and DYMO protocolfor various node densities. The simulation is done by using QualNet 6.1. The work in this paper has been modeled on GTS mechanism enabled IEEE 802.15.4 based wireless sensor network. It is observed through the simulation result that LAR outperforms DYMO in terms of PDR, delay, jitter and packets dropped for increased node densities. However the work is limited to fixed terrain size. Future work can be focused on investigation in the energy efficient algorithms, effect of adversary models and security mechanism to be incorporated in the routing protocols

References

[1]. *Jianping Zhu, Zhengsu Tao and Chunfeng Lv, "Performance evaluation for a beacon enabled IEEE 802.15.4 scheme with heterogeneous unsaturated conditions", International Journal of Electronics and Communications, Volume 66, No. 2, pp.93–106 ,February 2012*

[2]. *Woong Chul Choi and Seok Min Lee, "A Novel GTS Mechanism for Reliable Multihop Transmission in the IEEE 802.15.4 Network", International Journal of Distributed Sensor Networks, Article ID 796426, January 2012*

[3]. *Antonio-Javier Garcia-Sanchez, Felipe Garcia-Sanchez, David Rodenas-Herraiz and Joan Garcia-Haro, "On the synchronization of IEEE 802.15.5 wireless mesh sensor networks: Shortcomings and improvements", EURASIP Journal on Wireless Communications and Networking, Volumes 3, No.3, pp. 1-23,June 2012.*

[4]. *Yanjun Zhang, Siye Wang, Zhenyu Liu, Wenbiao Zhou, Dake Liu " Performance Analysis of Wireless Sensor Network Based on NS-2," Proceedings of International Conference on Systems and Informatics, Yantai , China, pp. 1445 – 1448, May 2012.*

[5]. *Pegatoquet, A.; Auguin, M. Jemaa, M.B, "An Efficient Mobility Management Approach for IEEE 802.15.4/ZigBee Nodes", Proceedings of Fourth International Conference on High Performance Computing and Communication, Liverpool, England, pp. 897 – 902,June 2012.*

[6]. *Paolo Baronti, Prashant Pillai et al, "Wireless sensor networks: A survey on the state of the art and the 802.15.4 and ZigBee standards" Journal of Computer Communications, Volume 30, No. 7, pp 1655-169,May, 2007*

[7]. *S. Mohanty, S.K. Patra. "Quality of service analysis in IEEE 802.15.4 mesh networks using MANET routing," Proceedings of International Conference on Computing Communication and Networking Technologies, Karur , Tamil Nadu,pp. 1-7, July 2010.*

[8]. *Z. Youling, W. Yi, M. Jianhua, J. Junpin, and W. Furong, "A low-latency GTS strategy in IEEE802.15.4 for industrial applications," Proceedings of the 2nd International Conference on Future Generation Communication and Networking, Hainan Island, China, pp. 411–414, December 2008.*

[9]. *IEEE 802.15.4 Standard-2003, Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR WPANs), IEEE SA Standards Board, 2003.*

[10]. *S. JunKeun, R. Jeong-Dong, K. SangCheol, K. JinWon, K. HaeYong, and M. PyeongSoo, "A dynamic GTS allocation algorithm in IEEE 802.15.4 for QoS guaranteed real-time applications," Proceedings of the IEEE International Symposium on Consumer Electronics, Irving, Texas, pp. 1–6, June 2007.*

[11]. *Adam Dahlstrom and Ramesh Rajagopalan, " Performance Analysis of Routing Protocols in Zigbee Non- Beacon Enabled WSN" ,Proceedings of IEEE Conference on Consumer Communications and Networking, Las Vegas, Nevada, pp.932-937, January 2013.*

[12]. *Y.B. Ko, N.H. Vaidya, Location-aided routing (LAR) in mobile Ad hoc networks, Proceedings of the Fourth Annual ACM/IEEE International Conference on MobileComputing and Networking, Dallas, Texas, Volume 6, No. 4, pp. 307-321, July 2000.*

[13]. *Mehran Abolhasan, Tadeusz Wysocki, Eryk Dutkiewicz, "A review of routing protocols for mobile Ad hoc networks" , Journal of Ad Hoc Networks, Volume 2, No. 1, pp.1–22, January 2004*

[14]. *P T V Bhuvaneswari and V Vaidehi, "Location Aided Energy Efficient Routing Protocol inWireless Sensor Network", International Journal of Simulation Systems, Science & Technology, Volume 11, No. 4,pp 41-50,July 2010.*

[15]. *www.scalable-network.com*

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