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Scenario dependent analysis of wireless networks for QOS metrics

Parul Khurana* and Inderdeep Aulakh
U.I.E.T Panjab University
Chandigarh, India
parulkhurana_11@yahoo.com*, ikaulakh@yahoo.com

***Abstract*—**As the new standards are emerging, wireless solutions are covering automation networks under its span. IEEE 802.15.4 is a standard for low-power, low-cost and short-range wireless networks and its major application fields are building automation, industrial sensor and actuator networks. It functions generally in the license-free 2.4-GHz scientific, industrial and medical band. This asset makes the technology easily applicable and also potentially vulnerable to interference by other technologies. There are several mutually existing scenarios with different network sizes which are gaining popularity in recent years. Theoretically, IEEE 802.15.4 is more suitable for resource-constraint ad-hoc network because of its low power consumption feature. However, performance of IEEE 802.11 is uncertain as the transmission power and receiver sensitivity are limited to match the level of IEEE 802.15.4. The focus of this paper is to quantify the behavior of IEEE 802.11 against IEEE 802.15.4 with the help of AODV routing protocol. Simulation results show that IEEE 802.11 overshadows IEEE 802.15.4 in terms of the packet delivery ratio, routing load and delay when we consider the node density. On the other hand, the average energy consumed by each node in IEEE 802.11 is lesser than that in IEEE 802.15.4 in both the scenarios. Moreover, the limited energy condition and transmission range of IEEE 802.11 is far less than that supported by IEEE 802.15.4. This is an economical setback for IEEE 802.11.

***Keywords*—**AODV, IEEE 802.11, Average End-to-End Delay, PDR, Energy Consumption, Wireless Sensor Networks

I. INTRODUCTION

With information technology growing rapidly and the increased requirements for large-scale communication infrastructures have triggered the era of Wireless sensor networks. The release of IEEE 802.15.4 has proven a milestone in wireless personal area networks and sensor networks. Here host of new applications can be benefited from the new standard (i.e. 802.15.4), such as those using sensors that control lights, wall switches, alarms, inventory tracking and many more. The main goal in wireless sensor networks is an efficient data packet transmission. Here, the sensor nodes collect the information, process it and send it to the base station. End-to-End delay is the most significant factor for assessing the Quality of Service. It is the time taken by a node, to sense, process and communicate with other nodes. It also depends on the scope of an application [1][15](Fig. 1). The 802.15.4 standard is basically designed as a flexible protocol in which a set of parameters is configured to meet different requirements and distinguishes itself from other wireless standards such as IEEE 802.11 [2] and Bluetooth [3] by some unique features. Therefore, a performance comparison research between IEEE 802.11 and 802.15.4 MAC layer [4][16] is presented in this paper at the AODV routing layer. Here main emphasis is given on End-to-End delay, but Energy consumption, Packet delivery ratio is also compared and analyzed. The effect of node density on the packet delivery ratio is also investigated and is observed that the transmissions of control packets are also affected. In the next section of this paper, a brief discussion of the MAC protocols is then followed by simulation results and conclusion.

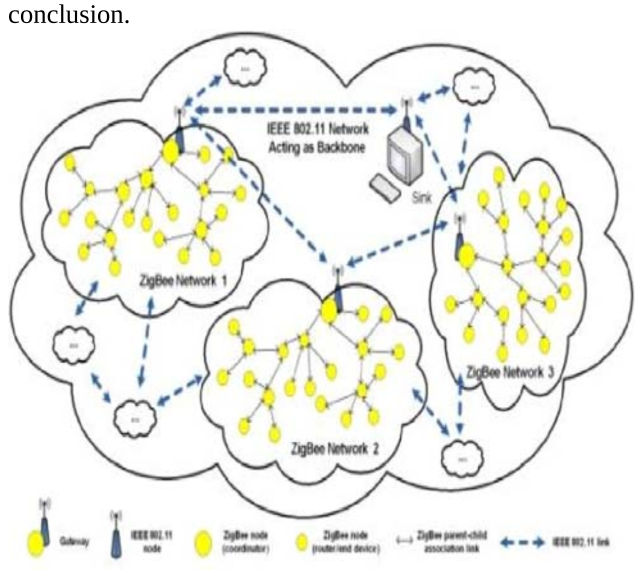

Figure. 1 Example of two-tired network architecture

II. MAC LAYER STANDARDS

In this section we would discuss the two wireless technologies of interest which have been standardized by the IEEE for the physical (PHY) and media access control (MAC) layer of wireless networks but aiming at different types of wireless devices and network configurations i.e. the IEEE 802.11 and 802.15.4 standards.

A. *IEEE 802.11 AND IEEE 802.15.4:*

The wireless LAN standard IEEE 802.11 was developed

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in order to specify an interface between a wireless client and a base station or an Access Point [9]. Many ad hoc users were benefitted with this as many points of attachment were established. In accordance with IEEE 802.11 standards the other IEEE 802.11a/b/g standards also use the MAC mechanism which basically specifies the arbitration of channel access under contentions among multiple wireless transmission devices. The difference among these WLAN standards is basically due to their transmission speed and carrier frequencies. The PHY layer of 802.11 WLAN generally focuses on the availability of bandwidth and task of using the correct modulation scheme. And on top of this PHY layer, the MAC layer operates as shown in Fig. 2.

The bandwidth offered by the PHY layer is distributed by the MAC layer which provides wireless connectivity to all the adjacent stations. Further this MAC layer defines Distributed Coordination Function (DCF) and Point Coordination Function (PCF) as its MAC layers. The DCF protocol employs Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and is mandatory, while PCF only supports the time-bounded delivery of data frames [9] and is optional. To avoid the hidden terminal problem and reduce interference the carrier sensing is combined with RTS/CTS mechanism in DCF protocol. While the IEEE 802.11 standard mainly focuses on features like data throughput, Ethernet matching speed, complexity to handle seamless roaming the WPANs in comparison concentrates on inexpensive solutions, less power consumption, short distances and wide range of small size devices that hardly require any infrastructure (Table 1). The working group of IEEE 802.15 currently specifies three classes of WPANs distinguished by battery drain, quality of service (QoS) and data rate i.e. 802.15.4 (ZigBee/LR-WPANs), 802.15.3 (UWB) and 802.15.1 (Bluetooth).

Table 1 The IEEE standard devices

	IEEE 802.11	**IEEE 802.15.4**
Battery Life	Few days	Multi month to
		Infinite
Bit Rate	300Mbps	250kbps
Range (without repeater)	100 m	300m

The IEEE 802.15.4 standard has been specifically designed for an ad hoc self-organizing environment intending to serve several portable applications and devices [5] thereby relaxing the needs of high data rate and QoS.

Similar to the PHY layer of IEEE 802.11, the IEEE 802.15.4 physical layer focuses on the bandwidth and the bit rates at which it works are 20 kbps, 40 kbps and 250 kbps [7] [8]. Along with this it specifies the receiver sensitivity as 85dBm for 2.4GHz and -92dBm for 868/915MHz. Basically the PHY layer acts as an interface between its radio channel and the MAC sub layer. Two services provided by this layer are the Data service and the Management service which are accessed by their service access points (SAPs) as shown in Fig 2.

The tasks performed at PHY layer are as follows:

i. The radio transceiver's activation and deactivation
ii. The current channel energy detection (ED)
iii. Received packets Link Quality Indication (LQI)
iv. Frequency selection of a channel
v. Clear Channel Assessment (CCA)
vi. Data transmission and reception in physical medium

Like the PHY layer, the MAC sub layer also provides two services - the MAC Data Service and the Management Service as shown Fig 2. Here the channel access can be in two modes, i.e. beacon-enabled and beaconless mode. In the beacon enabled mode the coordinator transmits periodic Beacons during the active channel duration for synchronization and information collection purpose [14]. Whereas in the beaconless mode a node can access a channel in its radio range as no time division is done and it uses unslotted CSMA/CA algorithm for this purpose. In this paper we use the beaconless operation as it has less transfer of traffic in the network.

The tasks performed at MAC layer are as follows:

i. Network beacons generation
ii. Beacon synchronization
iii. Association and dissociation of PAN (Personal Area Network)
iv. Channel access by using CSMA-CA mechanism
v. Guaranteed Time Slot (GTS) maintenance
vi. Establishing a reliable link between two MAC entities

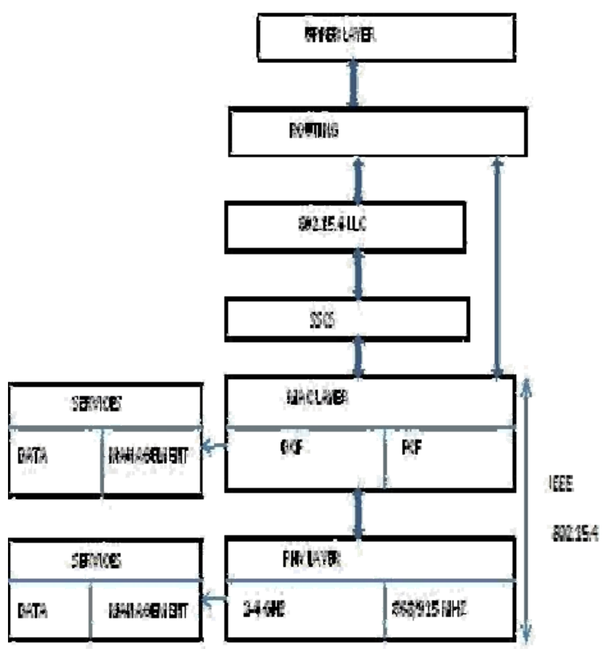

Figure 2. Layers of IEEE 802.15.4

III. ROUTING PROTOCOL

The routing protocols are generally designed for collision avoidance or prevention and faster data transmission. In this section we are going to discuss a flat routing protocol

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which does not require any central administrative system to handle the routing process, i.e. Ad hoc On-demand Distance Vector (AODV).

A. AODV:

AODV is one of the popular reactive routing protocols used for short range wireless communications. It is a self-starting protocol standardized in the IETF as experimental RFC 3561 [12][13] designed for ad hoc network. The AODV protocol has its various implementations like AODV-UU of Uppsala University [11].

Being an on demand protocol, it builds the routing path when demanded by the source node and uses a simple request-reply mechanism for the discovery of routes (Fig. 3). It uses hello messages for route discovery of a path from source to its sink. The larger number of mobile nodes attachment is possible here as every newly generated route gives a unique sequence number accordingly. These unique sequence numbers keep track of every node information for updating and information retrieval process. To resolve the conflict of which path to be chosen by the node we use the route with the greatest sequence number. Also to detect the stale path, we use these sequence numbers to retrieve the current and updated path information. Thereby, avoiding the loop problem and the problems generated from classical distance vector protocols [10].

B. Route Discovery in AODV:

A route discovery process is initiated when a packet is to be reached to its sink from a source and there is no valid route in the routing table. So during this process the packets are buffered. In Fig. 3, we can see that the source node A broadcasts route request (RREQ) packet to the whole network along with the RREQ identifier, the source and destination address, hop count and sequence number. Every node which receives the RREQ message replies with the RREP (route reply) message (Fig. 3) to the source node and updates its routing table. The connection is maintained as long as the source needs it. But if there is any link failure or inactive routes, a RERR (route error) message generated is forwarded to all the nodes. These nodes further transmit the RERR message to the nodes which are precursors to the unreachable destinations. Thus, the affected source node decides to either end the communication or initiate the discovery process by forwarding the new updated RREQ message.

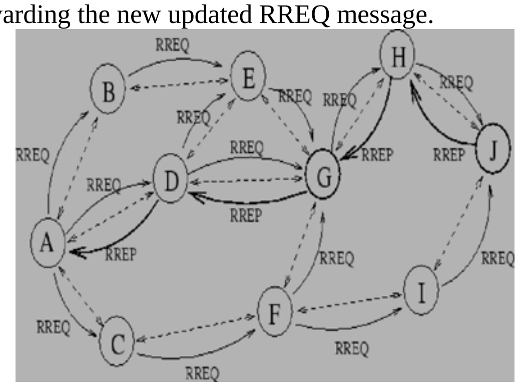

Figure. 3: Route Requests and Reply in AODV

AODV protocol follows the routing sequence numbers per hop similar to DSDV protocol and route discovery and maintenance technique similar to DSR protocol. Hence, it is a combination of DSDV and DSR protocol. Also, it is able to handle different mobility rates with a variety of data traffic levels in less processing time and small memory overhead when adapted to the dynamic environment [6]. For this reason, in this paper we concentrate on the performance of this on demand routing protocol AODV and analyze its performance for MAC layer protocols specifically IEEE 802.11 and IEEE 802.15.4.

IV. SIMULATION ENVIRONMENT AND RESULT

In this paper, we have used a discrete-event simulator NS2 (Network Simulator) for our simulation purpose because it is fully compatible with the transport protocols and results in accurate measurement. The implementation covered the essential functionalities except security and the contention free period which consisted of slot reservations for QoS application.To carry out the proposed simulation settings some extensions to the Mac layer were introduced. The simulation scenarios were run in a static environment with 'n' FFD nodes (varying from 5 to 30). We used the Constant Bit Rate CBR traffic for all simulation sessions..

Though 802.15.4 and Bluetooth are similar in there application area yet 802.15.4 and 802.11 are more comparable in terms of there performance. The 802.15.4 and 802.11 standards generally support multi-hop network topology and peer-to-peer communications. To evaluate the various performance behaviors of 802.15.4 we have used non-beacon enabled mode. The overall goal of this simulation study is to evaluate the performance of reactive routing protocol AODV for different node density and various number of nodes for both IEEE 802.11 and IEEE 802.15.4 standards. The simulations have been performed using the network simulator which provides scalable simulations in Wireless Networks. Here, we have performed simulation in two scenarios described as follows. In both the scenarios we use the same mobility model, topology, traffic and routing protocol.

A. Simulation Scenario-1:

In this scenario, the performance of the AODV routing protocol is evaluated by keeping the pause time (30s) and network speed (10mps) constant. While the network size (number of mobile nodes) is varied from 10 to 30 nodes. Table 1 shows the simulation parameters used in the evaluation.

Table 1 Simulation Parameter for Scenario-1

Simulation Parameters	**Parameter value**
Number of Nodes	10 to 30
Simulation time	2000 Seconds
Channel frequency	2.4GHz
Simulation Area	50 x 50 m2
Traffic Type	CBR
Routing Protocol	AODV

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Path Loss Model	Shado
MAC Model	IEEE 802.15.4 / IEEE 802.11
Energy Model	Energy Model
Initial Energy	100 Joules
Data Rate	20,40,60,80,100

Fig. 4 shows the snapshot of the AODV routing protocol in the network simulator for simulation scenario-1 with 10 nodes and speed of 20mps. The variation of Packet delivery ratio (PDR), Average End-to-End Delay, Normalised Routing load and energy consumed by varying the network size (nodes) as shown in Fig. 5, 6, 7 & 8 respectively.

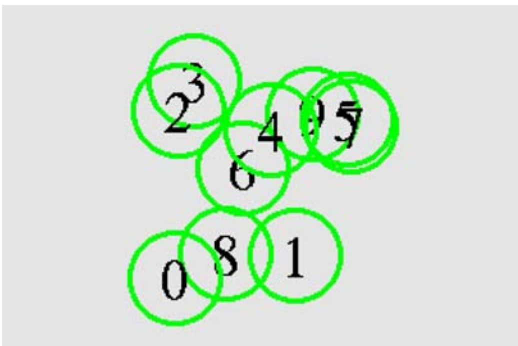

Figure 4: Simulation window for 10 nodes

It is clear from the Fig. 5 to Fig. 8 that in WPAN as the node density increases overhead increases which result in an increase in average end-to-end delay, normalized routing load and decrease in the PDR as compared to WLAN. It is also observed from Fig. 5 that as the node number increases the variation in the PDR is decreasing in WLAN as compared to WPAN, which shows a steep fall in its value and then a sudden rise with the increase in network size.

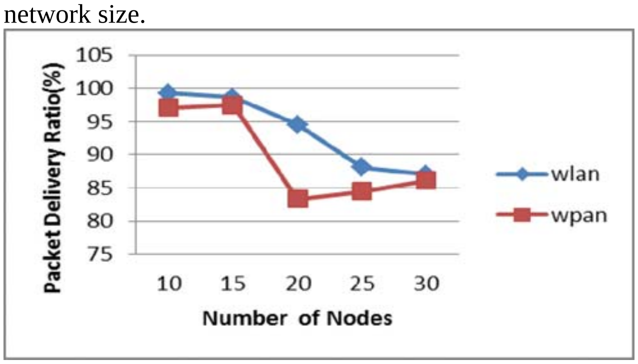

Figure. 5 PDR vs Number of Nodes

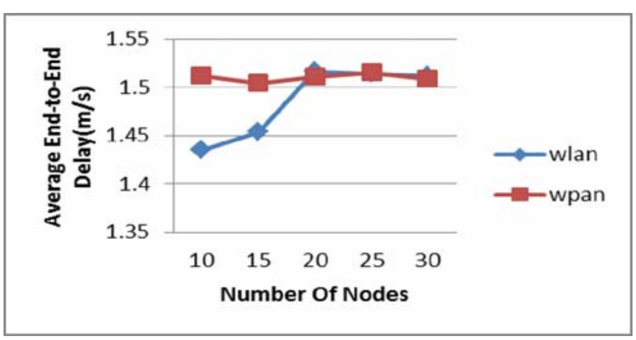

Figure. 6 Average End-to-End Delay vs Number of Nodes

B. *Simulation Scenario 2:*

In the second scenario we keep the network size (30 nodes) and pause time (30s) constant by varying the node density and the performance is evaluated thereafter. Table 2 shows the simulation parameters used in the evaluation.

Table 2 Simulation Parameter for Scenario-2

Simulation Parameters	**Parameter value**
Number of Nodes	30
Simulation time	1000 Seconds
Channel frequency	2.4GHz
Node Density	596, 1096, 2096, 3096, 4096
Mobility	Static
Routing Protocol	AODV
Path Loss Model	Shado
MAC Model	IEEE 802.15.4 / IEEE 802.11
Energy Model	Energy Model
Initial Energy	100 Joules
Data Rate	40 mps

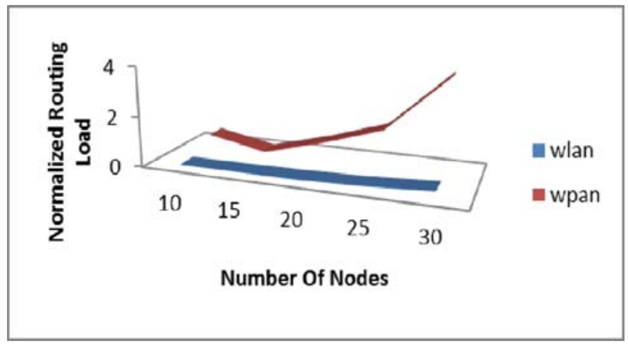

Figure. 7 NRL vs Number of Nodes

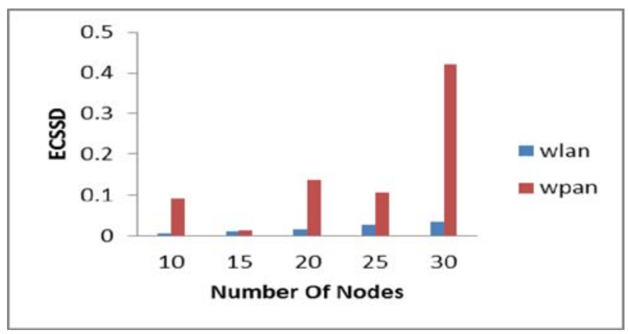

Figure. 8 ECSSD vs Number of Nodes

Fig. 9 shows the simulation for 30 nodes with variation in node density. The variation of Packet delivery ratio (PDR), Average End-to-End Delay, Normalized Routing load and energy consumed by varying the node density is shown in Fig. 10, 11, 12 and 13 respectively.

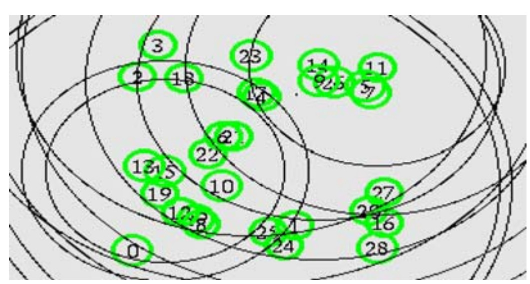

Figure. 9: Simulation window for 30 nodes

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From Fig. 12 and 13 it is observed that, in WPAN as the mobility increases according to the surface area the overhead increases.

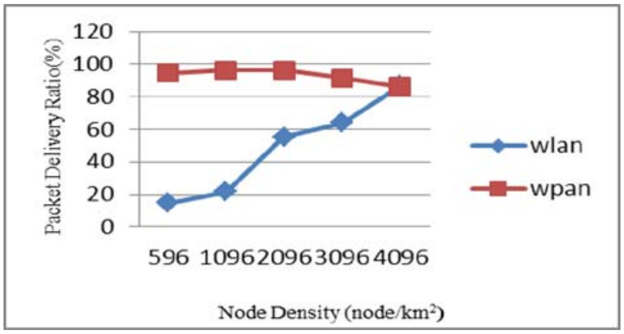

Figure. 10 PDR vs Node Density

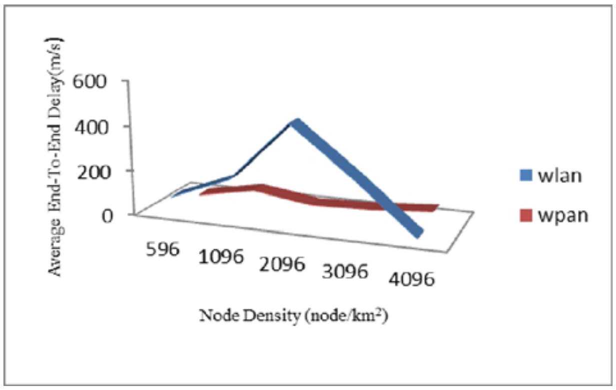

Figure. 11 Average End-to-End Delay vs Node Density

It is also observed from the Fig. 10 and 12 that the PDR and routing load is decreased for WPAN as compared to WLAN respectively.

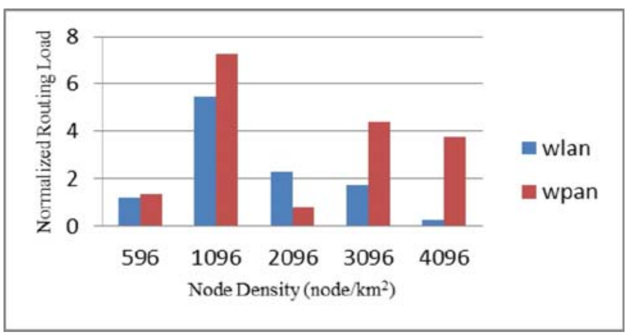

Figure. 12 NRL vs Node Density

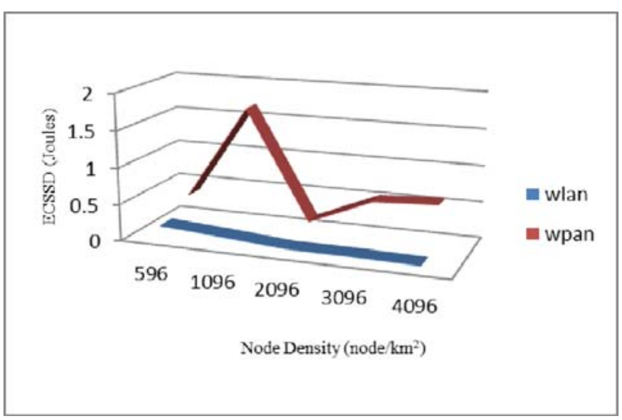

Figure. 13 ECSSD vs Node Density

V. CONCLUSION

The new IEEE 802.15.4 standard which is designed for low rate wireless personal area networks (LR-WPANs) has developed a host of new applications in emerging areas like automation, industrial control and many monitoring applications. The increasing demand for these real-time applications has made the Quality of Service (QoS) support for wireless sensor networks (WSN) a fairly new research framework. To evaluate the general performance of this new standard, we use an NS2 simulator and carry out the experiments by analyzing its performance along with the 802.11 standard. The impact of node density and varying network size on the QoS metrics has been studied. The simulation results show that AODV achieves better performance in an IEEE 802.11 WLAN environment as compared to IEEE 802.15.4 WPAN. The energy consumption is also low here. This is due to the limitations in range and power for WPAN. However, when the node placement is unattended there WPAN shows better performance as the delay is reduced and not much variation occurs in PDR in comparison to the WLAN. It is observed that overall Quality-Of-Service depends on proper selection of the routing protocol, for a particular application of wireless sensor network. The aim of the paper was to give an insight of how the information is transferred when using a reactive on demand protocol in two different environments. Future work may include analysis of various improvements of the proposed protocols including the Guaranteed Time Slot (GTS) allocation mechanism with the aim to analyze and evaluate network performances. The impact of the Beacon Order BO and the Super frame Order SO on the network performance can also be further studied.

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