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Research Article
A Comparison of Wireless Sensor Network Routing Protocols

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Abstract
The IEEE 802.15.4 Wireless Sensor Networks (WSNs) are network that are embedded into our environments for the purpose of monitoring the physical or environmental conditions, such as temperature, sound and vibration at various different locations. A WSN is characterized of having low-power, low-cost and autonomous sensor nodes equipped with a radio transceiver or other wireless communications device. Additionally, the WSN is characterized of being self-maintained in case one sensor is down the sensors can find another root to send the data without the help of any human. There are several protocols used in wireless sensor network for data collection and request disseminations. Two protocols: Flooding and convergecast protocols was focus. The behavior of flooding and convergecast protocols in a sensor network is simulated under different assumptions about the number of nodes, transmission power and the distance between nodes. It can be showed that varying the distance between nodes has no effect on the latency and mean number of hops. However, it has been found that the transmission power has an effect on the two protocols with regard to the mean number of hops and latency. As the transmission power increases, the number of hops and latency decrease.

Key words: WSNs, flooding protocol, convergecast protocol, routing algorithm, mean number of hops, mean latency, number of received packets, OMNET++ simulator

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INTRODUCTION

Wireless Sensor Networks (WSNs) have gained the interest of many applications recently due to the advances in communication technologies and electronics (Wang and Balasingham, 2010; Wei and Qi, 2011). This also can be explained due to the broad spectrum of innumerable applications (Biradar *et al*., 2009; Omer and Mattem, 2004). The WSN has many advantages, such an ease of deployment, fault of tolerance and accurate sensing, which enables it to be utilized in many fields, such as environment monitoring for large areas with respect to some physical quantities, biological detection, industrial sensing and transportation monitoring.

The WSNs are composed of large numbers of tiny disposable low power devices called nodes, which are relatively restricted in terms of energy, memory, as well as computational and transmission power (Singh *et al*., 2010). This enables it to be uniquely distributed in order to perform certain tasks. These nodes communicate with each other directly through a single hope transmission if the connection between source and destination is close or through other nodes (relays) otherwise (Akyildiz *et al*., 2002; Olariu *et al*., 2004; Shang *et al*., 2010). Relaying is a major advantage of sensor networks to come over the limitations of wireless transmission such as noise, selective fading, multipath propagation and attenuation, which reduce the quality of service and the coverage range of wireless communication (Alnawayseh, 2015). In addition, to achieve communication between nodes and to reach destination, nodes with repeated functionality are employed. The selection process of the optimal path toward destination and data processing in sensors are defined by routing protocol.

In this study, our focus was on two protocols: Flooding and convergecast protocols, to conclude the better suggested protocol for high speed WSNs application with less system complexity.

Flooding protocol is very popular protocol, where a node sends a message to all of its neighbors until the maximum number of hops for that message is reached or the message has reached its destination. This protocol is very basic protocol, one node send the information to all the nodes in the network. If the node first time receive the data it resend it to the all neighbors expect the one send the information if the information or data received more than once it ignore it (Singh *et al*., 2010). The flooding protocol is very simple, however, it is causing heavy traffic. Although the sensors drop the packets if it receive it more than one time and there is limit number of hops, travel for the packets further problems still exits (Gogic *et al*., 2013; Almazaydeh *et al*., 2010).

The convergecast protocol is the inverse of the broadcast, instead of the message propagating down from a single root to all nodes, data are collected from outlying nodes to the root. Typically, some function is applied to the incoming data at each node to summarize it, with the goal being that eventually the root obtains all the data in the entire system (Wang and Balasingham, 2010; Singh *et al*., 2010).

In this study, the behavior of flooding and convergecast protocols in a sensor network are simulated and examined under different assumptions about the number of nodes, transmission power and the distance between nodes. A comparison made between the two protocols regarding the mean number of hops and time latency as the time efficiency is one of the mean concerns in WSNs data transmission. It is shown that varying the distance between nodes has no effect on the latency and mean number of hops. However, it has been found that the transmission power has an effect on the two protocols with regard to the mean number of hops and latency. As the transmission power increases, the number of hops and latency decrease.

There are many network simulators tools, such as global mobile information systems information library (GloMoSim), optimized network engineering tools (OPNET), Network Simulator (NS-3) and objective module network test-bed (OMNET++) (Gogic *et al*., 2013; Varga, 2001). The OMNET++ can support a large number of network components, such as different applications, protocols and traffic models. In this study OMNET++ simulator is chosen to conduct this experiments.

ROUTING ALGORITHMS

There are several protocols and algorithms used in wireless sensor network for data collection and request disseminations (Al-Karaki and Kamal, 2004; Wei *et al*., 2012). Each of these algorithms are using different metrics for selecting the best rout. These metrics could be the least number of intermediate hops, the path with the lowest delay or the path with least power consumption. The routing protocols are classified into two main categories, proactive and reactive.

Proactive: In proactive routing each node maintains a table that contains the routes to any other node in the network. Nodes are regularly updating their tables using various table-driven protocols differ in the way how the information propagates through all nodes in the network when topology changes (Zheng and Jamalipour, 2009; Wei *et al*., 2014). A large amount of traffic is required to maintain the latest

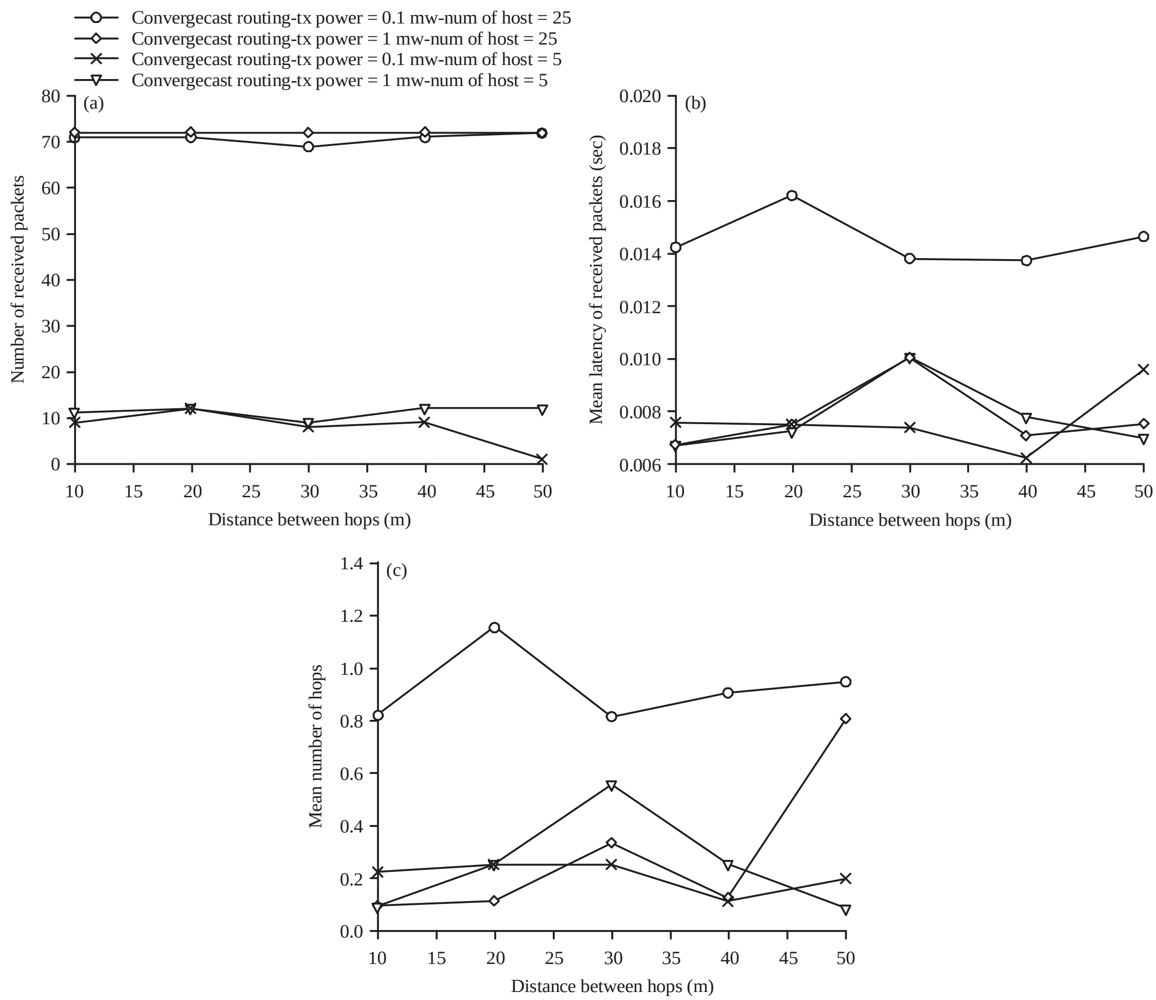

Fig. 1(a-c): Simulation results for convergecast protocol, (a) Number of received packets, (b) Mean latency of received packets and (c) Mean number of hops

information in these table, therefore, proactive routing protocol is not suitable for large network. Examples of such schemes are the conventional routing schemes: Destination Sequenced Distance Vector (DSDV), Bellman Ford protocol and Optimized Link State Protocol (OLSR) etc.

Reactive: Reactive routing is also known as on-demand, routes are acquired by nodes on demand when a packet needs to be forwarded since nodes do not maintain routing information or routing activity if there is no communication. If a node say node A wants to send a packet to another node say node B in the network then it starts the search for the rout to reach node A in an on-demand manner and establishes the connection, in which the data will be passed through to reach its destination. The advantage of reactive routing is that the nodes do not store information about the routes in the network. However, by acquiring routes on-demand, the network will be flooded with queries each time a packet is sent. The *ad hoc* On-demand Distance Vector (AODV) routing, Location Aided Routing (LAR) and Dynamic Source Routing (DSR) (Zheng and Jamalipour, 2009) are an example of a reactive protocol.

SIMULATION MODEL AND RESULTS

Simulator test bed (OMNET++ MiXiM): Objective module network test bed++ (OMNET++) is one of best network simulator as it provides a general purpose, open source and a discrete simulation environment (Varga, 2001). The main application area of OMNET++ is modeling and simulation of the advanced telecommunication systems. The MONET++ in this model is broadened with MiXiM frame work. The channel model within MiXiM take in account the antenna gain, path loss, fast and slow fading and shadowing (Gogic *et al*., 2013; Wessel *et al*., 2009). The path loss model utilized here in MiXiM is given as in Eq. 1 by Gogic *et al*. (2013):

$$\rho_r = p_t\left(\frac{\lambda}{4\pi}\right)\frac{1}{d^\alpha} \quad (1)$$

where, p_r and p_t are the power at transmitter and receiver node, d is the distance between transmitting and receiving WSN node, α is the path loss component and λ is the wavelength. All nodes are equipped with single transmitter and receiver. The channels between all nodes are assumed to be multi path fading channel with AWGN.

Simulation parameters: The behavior of flooding and convergecast protocols in a sensor network is simulated under different assumptions about the number of nodes, transmission power and the distance between nodes as shown in Table 1. Table 1 shows the transmission power were examined for two values 0.1 and 1 mw. And the distance between the nodes have been simulated for different values such as 10, 20, 30, 40 and 50 m. Also the number of nodes for a network varies between 5 and 25 nodes.

Simulation results and analysis: Figure 1a shows that the number of received packets by the sink node has increased as the size of the network increases from 5 nodes to 25 nodes. The transmission power has no effect on the number of packets received. Figure 1b shows that the mean latency is much more for the network with 25 nodes and this is expected. Figure 1c shows that there is no much difference regarding the mean number of hops between a network with 25 nodes and a network with 5 nodes. Figure 2a shows the transmission power has an effect on the number packet received by the sink node and it was higher when the transmission power has increased from 0.1 to 1 mw. Additionally, the transmission power has an effect on the mean latency and mean number of hops (Fig. 2b and c).

ANALYZING RESULTS AND DATA

Before staring the analysis, it is important to understand the limitations of OMNET++ simulator regarding the output data presentation. The output results of the convergecast protocol are presented in a scatter chart diagram, while for the flooding protocol is bar chart, which makes it difficult to compare the two protocols. Therefore, the data from the simulator is collected and recreated it in MS Excel to have better analysis. In this section the results are presented in professional manner to make it understandable and comparable. The simulation model is designed in two scenarios based on the size of the network to further investigate the two protocols:

Table 1: Flooding and convergecast protocols simulation parameters

Parameters	Values
No. of nodes	5 node:25 node
Network dimension	250×250 m
Size of data packet	50 byte
Mobility speed	2 mps
Carrier frequency	2.4 GHz
Traffic type	Periodic
MAC protocol	IEEE 802.11
Distance between nodes	10, 20, 30, 40 and 50 m
Simulation time	120 sec
Transmitted power	0.1:1 mw
Path loss component (α)	2

MAC: Media access control

- In the first scenario the size of the network is 25 nodes
- In the second scenario the size of the network is 5 nodes

First simulation scenario: The mean number of hops for both protocols convergecast and flooding of the first scenario is shown in Table 2. Where the number of host is 25 nodes and the distance between nodes are varied from 10, 20, 30, 40, and 50 m and the transmission power from 0.1 and 1 mw.

It can be noticed that the convergecast protocol shows a sharp decrease on the number of hops when the power equal to 1 mw comparing to the case when the power equal 0.1 mw. On the other hand, the flooding protocol has a larger number of hops used to send the data that is almost doubling the convergecast protocol for different values of distances (nodes positions) and transmitted power.

The mean latency for both protocols convergecast and flooding of the first scenario is shown in Table 3 with same assumptions of Table 2. It can be seen that the latency of the received packets reduced almost to half when the power of transmission is 1 mw comparing to the results collected from the simulator when the power of transmission is 0.1 mw. However, the during all tests run by the simulator it can be seen that the flooding protocol is slightly faster than the convergecast protocol because it have a less mean latency. Another important note should be considered here that is the variation of the time is reduced between the two protocols when the distances between nodes getting distant. This note much more clear at distances of: 30, 40 and 50 m.

Number of received packets for both protocols convergecast and flooding of the first scenario is shown in Table 4 with same assumption of Table 2. Convergecast protocol more packets are send comparing to the flooding protocol. This can be explained by the fact that flooding protocol is a simple protocol where each sensor sends data to all its neighbors without checking, where it comes from or where it should go. Moreover, in case the same packet is received by node more than once it is dropped, which cause more power consumption of the nodes in the networks. As for

Table 2: Mean number of hops with number of host = 25

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Mean number of hops for convergecast	0.8169	1.1549	0.81159	0.9014	0.94444	0.0972	0.1111	0.3333	0.125	0.805
Mean number of hops for flooding	2.42	2.61	2.67	2.88	2.65	1.96	2.70	2.26	2.09	2.17

Table 3: Mean latency with number of host = 25

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Mean latency for convergecast	0.0142	0.0162	0.0138	0.0137	0.0146	0.0067	0.007504	0.01005	0.0071	0.00753
Mean latency for flooding	0.00961	0.0122	0.0108	0.0118	0.0115	0.00542	0.00631	0.00760	0.00687	0.00703

Table 4: Number of received packets with host = 25

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Number of packets received for convergecast	71	71	69	71	72	72	72	72	72	72
Number of packets received for flooding	3.84	2.88	2.88	3.84	3.80	3.84	2.88	3.84	3.84	2.88

Table 5: Mean number of hops with host = 5

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Mean number of hops for convergecast	0.2222	0.25	0.25	0.1111	0.2	0.0909	0.25	0.5555	0.25	0.0833
Mean number of hops for flooding	1.73	1.80	1.80	1.98	2.30	1.60	1.70	1.85	1.70	1.65

Table 6: Mean latency with number of host = 5

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Mean latency for convergecast	0.00759	0.007479	0.00736	0.00622	0.0196	0.00672	0.007239	0.01009	0.0078	0.0070
Mean latency for flooding	0.00584	0.00726	0.00605	0.00577	0.00927	0.00484	0.00524	0.00527	0.00501	0.00484

Table 7: Number of received packets with number of host = 5

Distance between nodes (m)	10	20	30	40	50	10	20	30	40	50
Transmission power (mw)	0.1	0.1	0.1	0.1	0.1	1	1	1	1	1
Number of packets received for convergecast	9	12	8	9	1	11	12	9	12	12
Number of packets received for flooding	2	1.60	1.60	2.80	2.20	3	3.20	3.20	3.20	3.20

the convergecast, it needs to have the information about the source of data and the destination it should reach, therefore, power consumption in this protocol is reduced by controlling resending process. Moreover, the large number of nodes in network causes the number of received packets to be eventually large too. Consequently, in flooding protocol less number of packets is deployed comparing to the Convergecast protocol.

Second simulation scenario: The mean number of hops for both protocols convergecast and flooding of the second scenario is shown in Table 5. Where the number of host is 5 nodes and the distance between nodes are varied from 10, 20, 30, 40 and 50 m and the transmission power from 0.1 and 1 mw.

It can be noticed clearly that the convergecast protocol use less number of hops to send data over the network comparing to the flooding protocol that use much more hops. Moreover, it is obvious that the mean value is almost the same in case of power transmission is 0.1 or 1 mw. However, an important observation is obtained for one of the test experiment is that convergecast protocol use more number of hops comparing to other flooding protocol experiments when the distance is 50 m and power transmission is 0.1 mw. Therefore, it can be indicated as an out layer and need to be studied more. In as for the flooding protocol, the mean number of hops does not vary too much from each other except for the distance of 50 m and power transmission 0.1 mw, which is considered as a peak result of the whole test.

The mean latency for both protocols convergecast and flooding of the second scenario is shown in Table 6 with same parameters of Table 5. In flooding protocol the mean latency is slightly reduced comparing to the convergecast protocol except for one test the reduction is sharp when the distance is 50 m and power transmission 0.1 mw. For the rest of the test results the variation is more visible and showing difference between the two protocols.

Number of received packets for both protocols convergecast and flooding of the second scenario is shown in Table 7 with same parameters of Table 5. It can be obtained

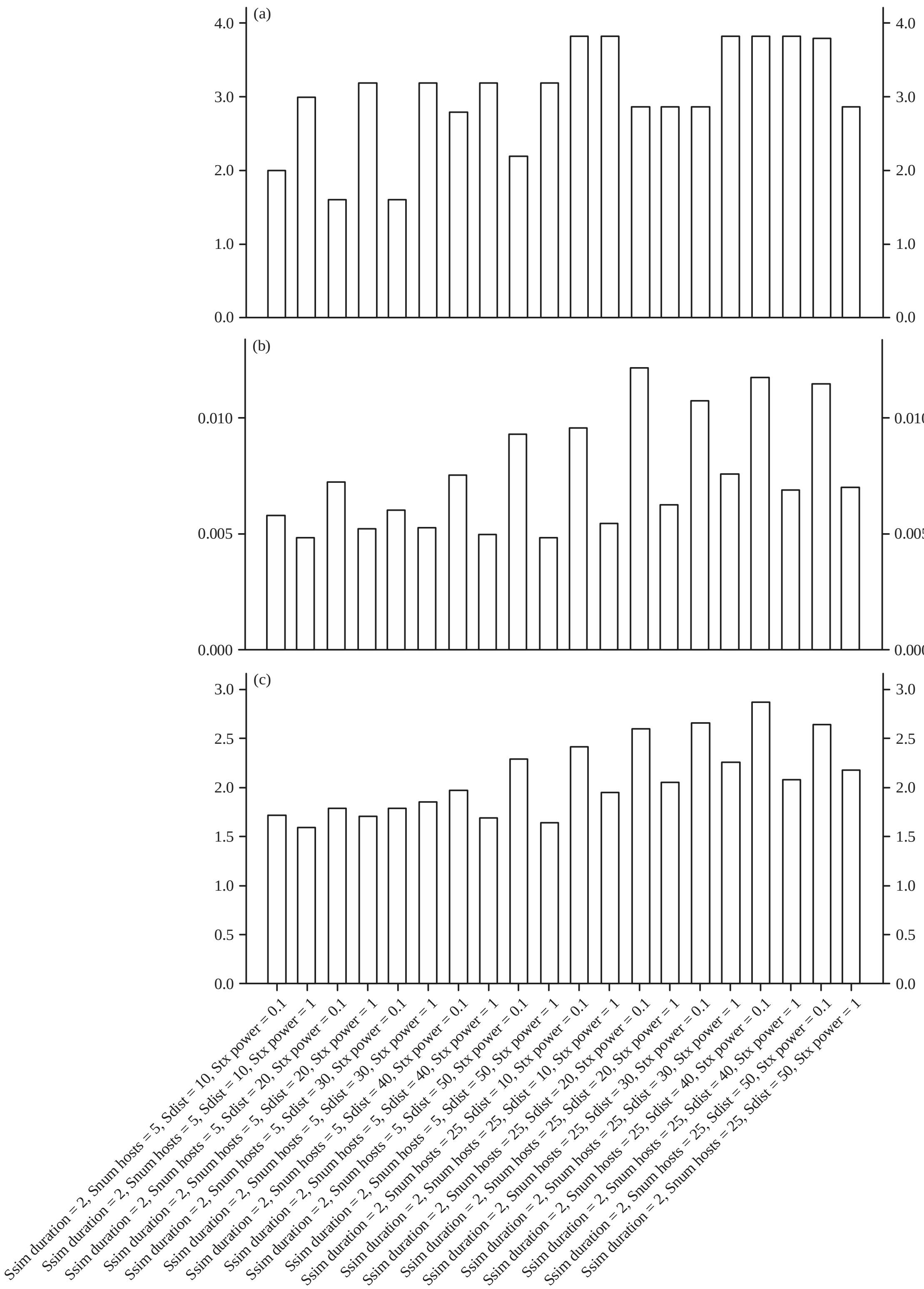

Fig. 2(a-c): Simulation results for flooding protocol, (a) Number of received packet, (b) Mean latency and (c) Mean number of hops

that more packets are send by convergecast protocol than flooding protocol through all tests with the exception of one test where distance is 50 m and power broadcast is 0.1 mw. Remarkably, convergecast send less number of packets than flooding. As for the flooding protocol the values are almost the same for all tests, which is similar pattern with scenario 1.

However, number of received packets with power transmission of 1 mw is slightly more than results with power transmission of 0.1 mw.

DISCUSSION

Researchers have introduced numerous routing protocols and these protocols have been analyzed using WSN simulators. Performance comparison among routing protocols are performed. For example performance comparison are made among DSDV, DSR, AODV and TORA (Broch *et al*., 1998), performance of SPF, EXBF, DSDV, TORA, DSR and AODV (Das *et al*., 2000a), comparison of DSR and AODV (Das *et al*., 2000b), performance of STAR, AODV and DSR (Jiang and Garcia-Luna-Aceves, 2001), comparison of AM Route, ODMRP, AMRIS and CAMP (Broch *et al*., 1998), comparison of DSDV, OLSR and AODV (Azadm *et al*., 2007) and many more. These performance comparisons are carried out in wireless networks. The work introduced in this study is unique and comprehensive. The behavior of flooding and convergecast protocols in a sensor network is simulated under different assumptions about the number of nodes, transmission power and the distance between nodes. Solid results presented about the performance of the two protocols under mentioned parameters, which introduce a clear guidelines for designer to better assumptions for certain applications.

CONCLUSION

After the analysis of the two scenarios, many assumptions have been studied about the two examined protocols efficiency. As a reminder, the study based on the evaluation of the mean number of hops used, the mean latency and the number of received packets.

In the first scenario with the number of nodes is 25 and the power transmission varying between 0.1-1 mw and the distances are 10, 20, 30, 40 and 50 m. It has been found that the in convergecast protocol a less number of hops is used to send the data through the network comparing to the flooding protocol that uses further number of nodes. As for the latency, the simulations proofed that in flooding protocol latency is slightly less than the case in convergecast protocol. In the last comparison of the first scenario it is obvious that the number of received packets for convergecast protocol is more than comparing to the flooding protocol.

In the second scenario with the number of nodes equal 5 with power transmission 1 or 0.1 mw and the distance are 10, 20, 30, 40 and 50 m. The pattern repeat itself and it shows that the convergecast use less number of hops to send the data through the network on the contrary the flooding uses more nodes to send the data. For the mean latency the flooding is less than convergecast with little differences that can be negligible. In the last comparison regarding the number of received packets it has been obtained that the convergecast protocol sends more packets than flooding protocol.

It can be founded that varying the distance between nodes has no effect on the latency and mean number of hops. However, it was illustrated that the transmission power has an effect on the two protocols with regard to the mean number of hops and latency. As the transmission power increases, the number of hops and latency decrease.

Additionally, the convergecast protocol uses less number of hops in the two scenarios but flooding protocol has better performance regarding the mean time latency and the numbers of packets sent.

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