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A Review of LEACH Protocol In Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) have emerged as an important area of research in wireless technology. It consists of a large number of tiny sensor nodes used for gathering data from the environment .It suffers from various challenges such as low bandwidth, and energy consumption, etc. Based on the network topology, routing protocols in sensor networks can be classified as flat-based routing, hierarchical-based routing, location-based routing, network flow and Qos based routing. Low Energy Adaptive Clustering Hierarchy (LEACH) is an energy-efficient hierarchical-based routing protocol very widely used in communication using WSN. This paper focus on the study and analysis of LEACH protocol in NS2 simulator based upon parameters like throughput, delay and packet delivery ratio. The results of the experiment showed that the selected protocol outperform in terms of metrics.

Keywords: Wireless Sensor Networks (WSNs), LEACH, Clustering protocol, Throughput analysis, Delay, Packet delivery ratio

Introduction

Wireless sensor network (WSN) is a growing technology that has gained the attention of many researchers due to their ability to monitor and conspire the physical world. It finds its applications in areas such as military surveillance, environmental monitoring, medical service, and industrial sensing (Akyildiz et al., 2002; Singh et al., 2010). Sensor network comprises of many number of tiny sensor nodes that are randomly distributed over an area of interest. A sensor node is a small device that collects data from its surrounding environment, carry out minimal computations, and exchange information with other sensors by means of wireless communication channels (Zahmati et al., 2007). Micro sensors in the WSN play a vital role in achieving the data collection, aggregation and communication from a remote monitoring environment (Chandrakasan et al., 1999). The sensor nodes are generally deployed randomly in an untethered environment to monitor the surroundings and send back the information to the base station (BS). (Zheng and Jamalipour, 2009).

In many WSN applications, the sensor nodes are deployed in an ad hoc manner without any layout formulation. Sensor nodes are usually battery-powered and are expected to operate without any intervention for a quite long period of time. Therefore it is impossible to change or recharge batteries of the sensor nodes in such cases (Akkaya and Younis, 2005). Thus the sensor nodes need to utilize the battery power efficiently in order to increase the network lifetime (Dhulipala et al., 2010). Owing to the severe energy constraints of the large number of densely deployed sensor nodes, it needs a relevant set of network protocols to implement different network control and management functions such as synchronization, node localization, and network security (Misra, 2009). It therefore creates many challenges to the design and management of WSN along with deployment of nodes. Energy consumption plays a crucial role in influencing the lifetime of the sensor node (Dai et al., 2009). A data aggregation scheme is proposed to achieve maximum lifetime and it is efficient in terms of network lifetime and energy gain (Liang et al., 2011).The optimized lifetime of WSN is not only based on single node but also on the entire network lifetime (Guo et al., 2010). A framework was proposed for lifetime enhancement that decreases the dead speed of the nodes leading to reliable inter cluster communication (Dhulipala et al., 2012).

Routing is a challenging process in sensor networks (Stojmenovic and Olariu, 2005). Routing protocol finds its place different from that of the existing communication mechanism due to numerous characteristics. First is that, it is difficult to construct a global addressing scheme for deployment of such large number of nodes. Hence traditional IP-based protocols are not suitable. Then the flow of sensed data from multiple sensor nodes to the sink node occurs in case of WSN which is in contrary to typical communication networks. Third is the occurrence of data redundancy since the same data could be generated by multiple sensors of the neighborhood. And at last the sensor nodes are tightly constrained in terms of battery power, transmission power, processing capacity and storage.

This investigation study is done by using widely perceived and enhanced network simulator NS-2 version 2.29 incorporated with Mannasim for WSNs, with necessary modification on NS-2 files and TCL scripts for implementation of the LEACH routing protocol.

The remainder of this paper is systematized as follows. Section 2 gives the overview of routing protocols. Section 3 describes LEACH protocol. Analyzes and simulation results are given in Section 4. Section 5 concludes the work done in this paper.

Routing Protocols Overview

Routing protocols in WSNs do not have any infrastructure. Here the sensor nodes often fail; wireless links are unreliable and have strong energy saving requirements

(Kulik et al., 2002). The protocols are classified as flat-based, hierarchical, location-based, network and QoS-based protocols.

Flat-Based Routing

All nodes in the topology are assigned the same functionality. As the number of nodes is large, it is not plausible to assign a global identifier to each node which provides way for data-centric protocols. In data-centric protocols, when the source nodes send their data to the sink, intermediate sensors carry out some kind of aggregation of the data originating from multiple sources and send the aggregated data to the sink node. They are query-based and depend on the naming of desired data, which helps in eliminating many redundant transmissions. Examples include Directed Diffusion (Intanagonwiwat et al., 2000), Rumor Routing (Braginsky and Estrin, 2002), COUGAR (Yao and Gehrke, 2002)**,** ACQUIRE (Sadagopan et al., 2005), EAD (Cheng et al., 2003), Information-Directed Routing(Liu et al., 2005),Gradient-Based Routing(Schurgers and Srivastava, 2001), Energy-aware routing(Vidhyapriya and Vanathi, 2007), and so on.

Hierarchical-Based Routing

All nodes are having different functionalities based on a hierarchy (Bandyopadhyay and Coyle, 2003). Hierarchical protocol aim to save energy via clustering the nodes, so cluster heads can do some aggregation and reduction of data. The processing of data is from lower clustered layer to a higher layer. As it hops from one layer to another one it covers larger distances making the data to move faster to BS. Clustering provides intrinsic optimization facilities at the cluster heads. It is an efficient way to lower energy consumption within a cluster as it complies data aggregation and fusion to decrease the number of transmitted messages with the BS. Hierarchical routing is mainly a two-layer routing where one layer is used to select clusterhead and the other layer is used for routing. Some of the protocols are LEACH (Yassein et al., 2009),PEGASIS(Power-Efficient Gathering in Sensor Information Systems)(Lindsey and , Raghavendra, 2002), HEED(Hybrid Energy-Efficient Distributed clustering) (Kour and Sharma, 2010),TEEN(Threshold-Sensitive Energy Efficient Protocols)(Heinzelman et al., 2000), And APTEEN(Adaptive Periodic TEEN) (Manjeshwar and Agarwal, 2002).

Location-Based Routing:

In location based routing, the sensor nodes are addressed by means of their locations. Routing path is chosen based on the position of sensor nodes in the field and therefore it utilizes the position information to communicate the data to the required area of interest fairly than the whole network. The location information can be obtained from neighbors or through GPS receivers. Certain location based schemes demand that nodes should go to sleep if there is no activity in order to save energy. Some examples include GEAR (Geographic and Energy-Aware Routing) (Yangy et al., 2009), Span(Chen et al., 2002) TBF(Trajectory-Based Forwarding)(Jeong et al., 2011).

Network-Flow and Qos Based Routing

In QoS-based routing protocols, the network has to harmonize between energy consumption and quality of data (Fonoage et al., 2010). The network needs to satisfy some QoS metrics such as delay, energy, bandwidth and so on while communicating data to the Base station. Examples include Maximum lifetime energy routing (Chang and Tassiulas, 2000), SAR (Sequential Assignment Routing) (Sohrabi et al., 2000) and SPEED(Stateless Geographic Non-Deterministic forwarding)(He et al., 2003).

The recent advance in WSN has led to a number of network routing protocols. Due to the high correlation of the data from the neighboring nodes, some protocols adopted cluster based network architectures to collect data. PEGASIS (Lindsey and Raghavendra, 2002) is a chain-based protocol that minimizes the energy consumption at each sensor node. APTEEN (Manjeshwar and Agarwal, 2002) uses an enhanced TDMA schedule to resourcefully integrate query handling. In addition to the protocols above, the LEACH (Yassein et al., 2009) protocol offered here provides appropriate solution to the data aggregation problem. Here clusters are created in a self-organized manner to bind data before transmitting to the end user. In LEACH, an elected node in every cluster, called the cluster head collects and aggregates the data from sensors in its cluster and transmits the result to the user.

Simulation of Leach Protocol

LEACH is a clustering-based protocol which reduces the energy dissipation in sensor networks. It selects the cluster-heads randomly and conducts re-election periodically in-order to communicate with BS in the network. Each cycle of selection the process includes two phase, set-up and steady phase (Murthy and Manoj, 2004)

In set-up phase, each sensor node selects a random number between 0 and 1, if it is lower than the threshold for node n, the sensor node becomes a cluster-head. The threshold T(n) is calculated as

$$T(n) = \begin{cases} \dfrac{P}{1 - P[r \times mod((1|P)]} & if\ n\ \varepsilon\ G \\ 0 & otherwise, \end{cases}$$

Where P is the desired percentage of nodes which are cluster-heads, r is the current round, and G is the set of nodes that has not been cluster-heads in the past 1/P rounds. This ensures that all sensor nodes eventually spend equal energy. After selection, the cluster-heads announces their selection of all nodes to elect their nearest cluster –head when they receive advertisements based on the received signal strength and then assigns a TDMA schedule for their cluster members.

The steady phase has a longer duration in order to minimize the overhead of cluster formation. Here also the data transmission takes place like set-up phase and the cluster-heads perform data aggregation through local computation. The BS receives only aggregated data from cluster-heads, which leads to energy conservation. After a certain period of time in the steady phase, cluster-heads are selected again through the set-up phase.

Simulation and Result Analysis:

Simulation Parameters:
We simulated the Leach protocol using the NS 2.29 Mannasim patch. The simulation is conducted by varying the number of nodes, simulation time, and transmission range and analyzed the performance of the network in terms of throughput, delay and packet delivery ratio.

Table 1: Simulation parameters

Parameter	Value
Terrain (in m^2)	1000x1000
Node Density	20,60,100,140
Simulation Time(s)	100,200
Propagation Model	Propagation/TwoRay Ground
Antenna model	Antenna/Omni antenna
Mac type	802.11
Link layer type	LL
Interface queue type	Queue/Droptail
Battery	Energy/Model/Battery
Min packet in ifq	50
Optimized number of clusters	5
Initial Energy (in Joules)	1
Transmission range (in m^2)	10,25,50,100

We simulated the LEACH protocol with terrain dimensions of 1000x1000 m^2 area by varying the node density from 20 to 140 for a simulation time of 100 and 200 Seconds. The initial energy of the node is chosen as a constant value of 1 joule. Transmission range is varied as through 10, 25, 50 and 100 respectively for better utilization of terrain and node capabilities for performance measurement and reliable communication.

Simulation Results

From the simulation results, we can see that the throughput of a network increases as the number of nodes increases with respect to transmission range. The transmission range of the sensor nodes is varied such as 10m, 25m, 50m and 100m with respect to the number of nodes and simulation time.

Fig.1 shows the throughput of the network when the simulation time is 100 Seconds. It is observed that it achieves higher throughput when the number of nodes and transmission range is more.

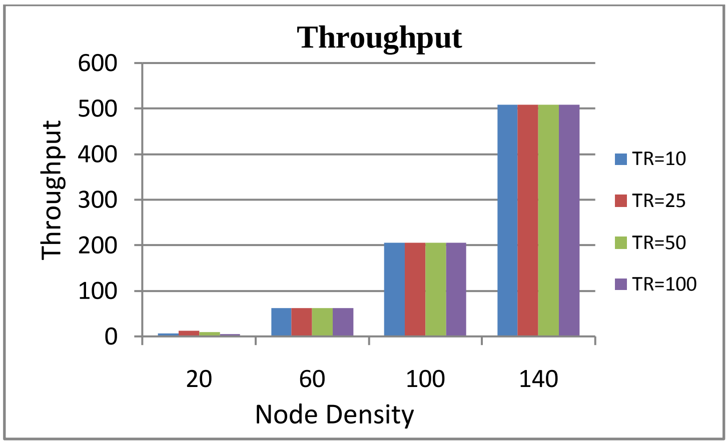


Figure 1: Network throughput over Transmission range

Fig.2 shows that the throughput gradually increases as the number of nodes increases. It is due to the increased number of nodes in packet transmission. When the simulation time is short, the network attains maximum throughput. LEACH showed better performance in throughput with the number of nodes when compared with AODV and DSDV protocols (Kansal et al., 2010).

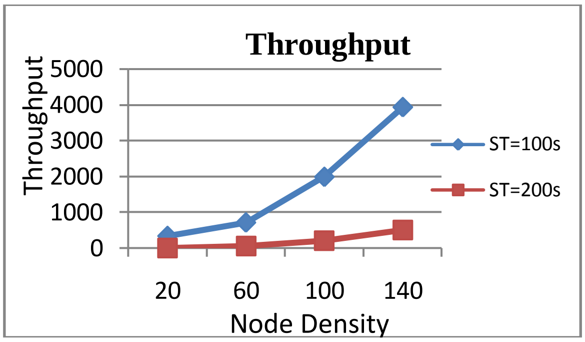


Figure 2: Network throughput over Simulation Time when Transmission range=10m

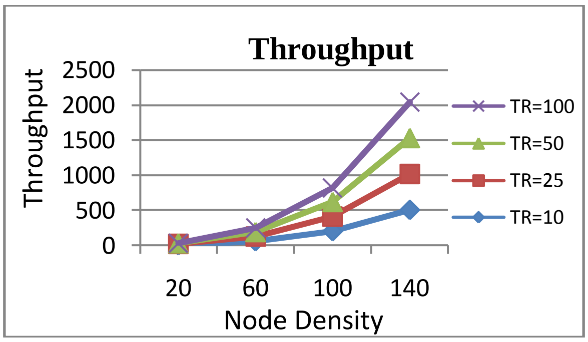
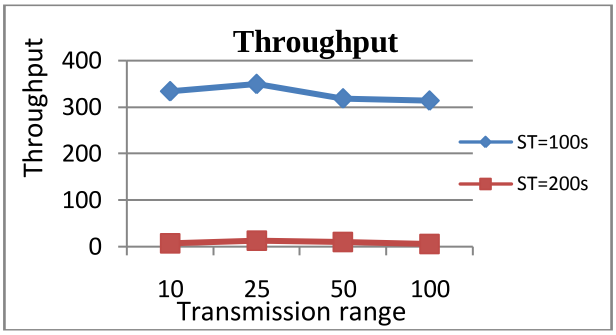


Figure 3: Network throughput

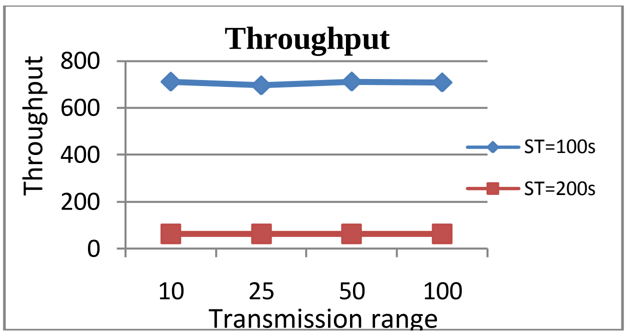
When the simulation time is 200s, and the network density is varied for different transmission ranges, the throughput of the network increases and reaches a maximum as in Fig. 3. Since the density of the network is more, the number of nodes that take place in packet transmission is also increased resulting in greater transmission.

Fig.4 shows the impact of transmission range over various node densities. Here the throughput is calculated by varying transmission ranges over different simulation times. Node density is kept at a constant of 20, 60, 100 and 140 for these simulations. Fig. 4(a) shows the throughput of the network for various transmission ranges with a constant node density of 20. It increases steeply first, reaches a maximum and drops suddenly for a smaller number of nodes. The network has maximum throughput when the simulation time is 100s and when the simulation time is increased the throughput falls short since the amount of packet transmission is higher.

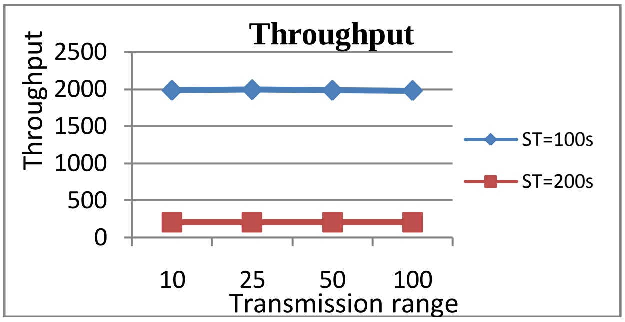
Fig. 4(b) shows the throughput of the network which falls nearly to 700Kb/Seconds for the network density of 60 nodes. From Fig. 4(c) it is as well observed that when the network size is increased by 5 times, the throughput increases by six times. Fig. 4(d) shows the throughput increased by 11 times compared with the network of 20 nodes.



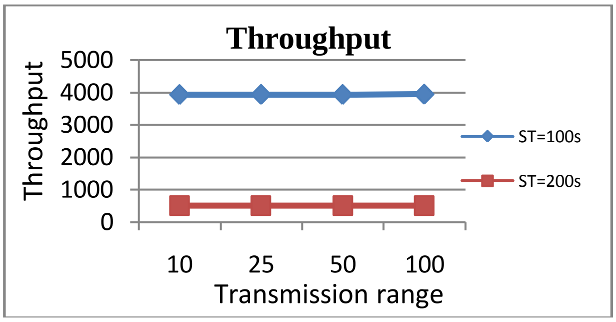
(a) Node density=20



(b) Node density=60



(c) Node density=100



(d) Node density=140

Figure 4: Impact of Transmission range for varying Node density

Fig.5 shows the throughput of the network over transmission range. As we can see that the throughput does not vary much for a constant node density. It reaches a higher throughput when the transmission range is small because of the faster transmission. Therefore nodes with higher transmission range has relatively lower throughput than with low transmission range. It also has maximum throughput when the network has a larger number of nodes.

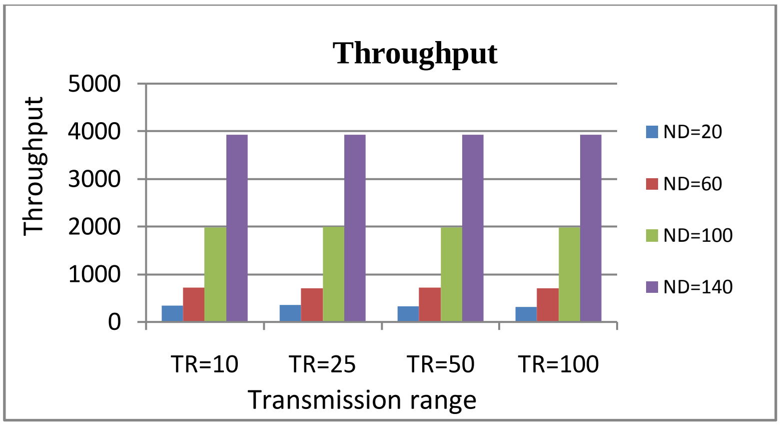


Figure 5: Throughput Vs Transmission range

From Fig.6 we see that the average end-to-end delay become very high and increases as the number of nodes increases with respect to both simulation time and transmission range. It has occurred since the packet receiving time of the node is higher when the transmission range of the sending node is more. Therefore Leach provides minimum delay when the transmission range is lower.

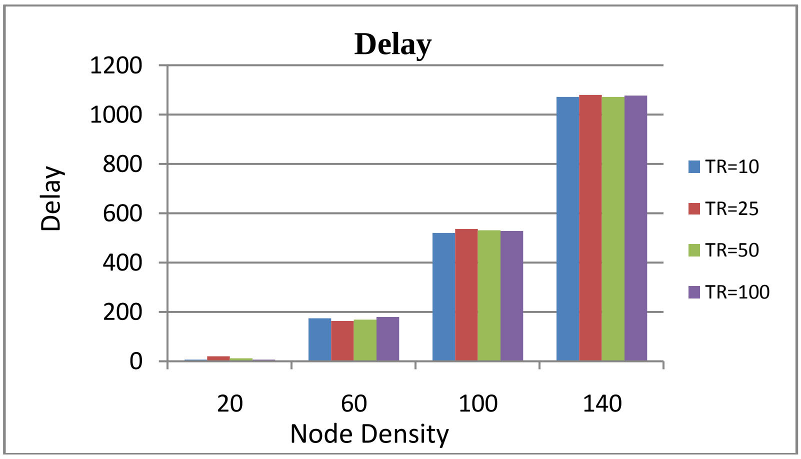


Figure 6: Average end-to-end delay

Fig.7 shows the comparison of average end-to-end delay for different simulation times. Minimum delay occurs when the simulation time is short as the number of packet transmission is lower in simulation of 100s. Additionally, the average end-to-end delay increases as the node density is increased LEACH showed minimum delay when the network has smaller number of nodes compared to AODV and DSDV (Kansal et al., 2010)

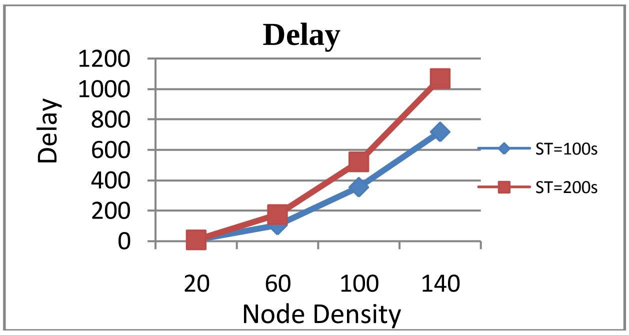


Figure 7: Average end-to-end delay when Transmission range=10m

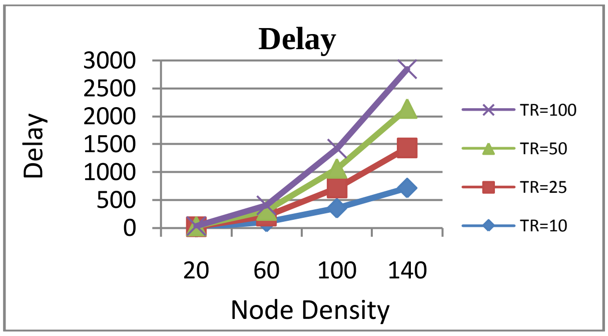
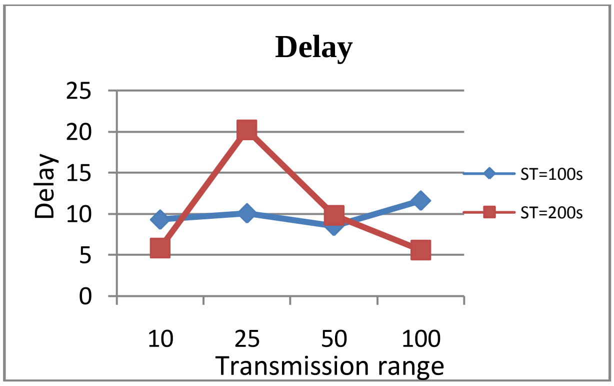


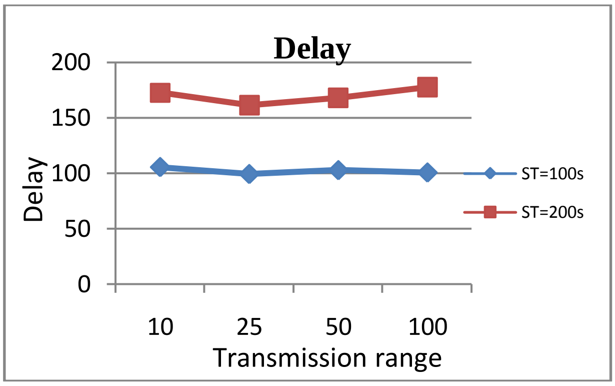
Figure 8: Average end-to-end delay

From fig. 8 it can be observed that the delay is minimum when the network has smaller number of nodes and lower transmission range. Thus when the node density and transmission range increases, delay is also boosted. Similar case is observed when the simulation time is increased. Smaller node density in smaller terrain causes minimum delay as it takes a minimum number of hops to reach the destination (Sivaraman et al., 2009).

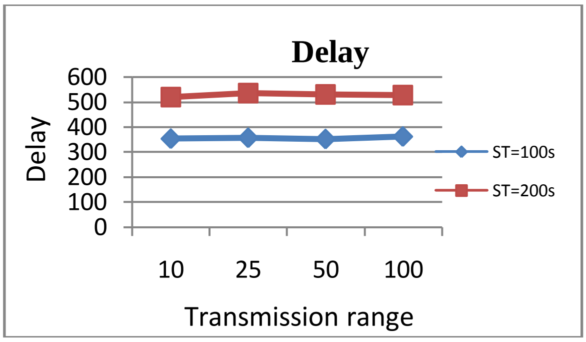
Fig. 9 shows the impact of delay in the network for various node densities. Fig.9 (a) shows the delay that occurs when the transmission range and simulation time is varied. When the simulation time is 100s, the delay first increases, then decreases and again increases as is the case in simulation of 200s except that it starts decreasing as transmission range increases. However in all the other cases the delay in the network is more when the simulation time is greater. Fig. 9(b) shows the greater delay compared to node density of 20. The delay reaches a maximum when the transmission range augments since the transmission time is greater. From Fig. 9(c) it is inferred that the delay increases by three times for 100 nodes with a simulation time of 100 seconds compared to Fig. 9(b). Finally from Fig. 9(d) it is examined that the delay in the network reaches a maximum when the transmission range and the simulation time is increased.



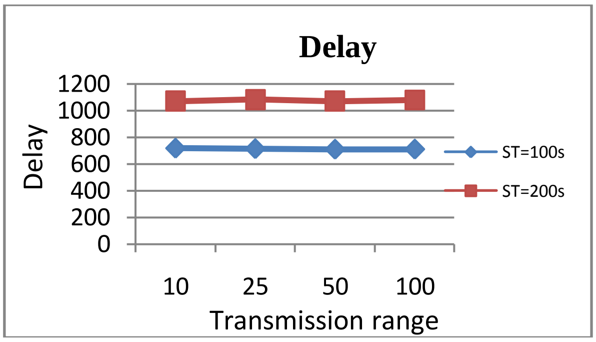
(a) Node density=20



(b) Node density=60



(c) Node density=100



(d) Node density=140

Figure 9: Impact of delay over Transmission range of various Node densities

The Fig. 10 shows the overall delay in the network for different transmission range and node densities. It can be observed that the network has a minimum delay when the node density is lower and has a maximum delay for higher node density. Seeing that the transmission range varies, the delay also varies but with minimum variation.

But the delay that occurs in a smaller transmission range is lower compared to the delay that occurs with a higher transmission range.

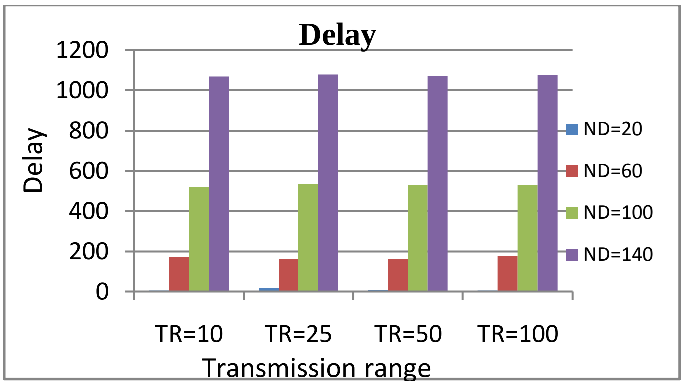


Figure 10: Delay Vs Transmission range

Based on Fig. 11 the packet delivery ratio of the network is greater when the simulation time is 200s. We could also see that there is a steep increase in the packet delivery as the number of nodes increases. When the node density is 20, the PDR first increases, then decreases and finally has maximum value. Whereas in other cases the ratio is obtained as constant as the ratio between the numbers of packets transmitted to the number of packets received is similar in those cases. LEACH showed a stable increase in the PDR and has better performance compared to AODV and DSDV with respect to the node density (Kansal et al., 2010; Dwivedi et al., 2009).

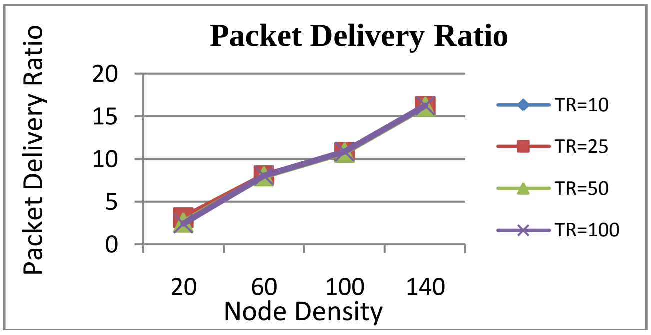


Figure 11: Packet delivery ratio

Conclusion

LEACH is a hierarchical routing protocol used in cluster based wireless sensor networks. We have presented an extensive simulation study analysis of the same in networks with difference in node density, transmission range and simulation time, using a variety of workloads such as throughput, delay, and packet delivery ratio. From the results we could say that as the throughput and delay are directly proportional to node density. As the node density decreases the throughput also decreases. Throughput is indirectly proportional to the transmission range and delay is directly proportional to the transmission range. Similarly the packet delivery ratio is proportional to node density. Thus LEACH is best suited for monitoring applications where the network needs to have higher packet transmission.

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