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# Comparison of Routing Protocols to Assess Network Lifetime of WSN

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**Abstract**

Rapid pace of improving technology in Wireless Sensor Networks (WSN) made it possible to manufacture low power, multifunctional sensor nodes. WSN is the set of small power energy confined sensor nodes which can be deployed in unapproachable domains. In WNS biggest constraint is to employ an efficient power consumption scheme. Different protocols were described for WSN out of which the research has been done on hierarchical (clustering) protocols to find out longer network lifetime. Low Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient GAthering in Sensor Information System (PEGASIS) and Virtual Grid Array (VGA) protocols were analyzed for network lifetime by changing the sensing range of sensor nodes and increasing the network size. The sensing ranges used are 8m and 12m for 60, 90 and 120 number of nodes. The results found that PEGASIS had the consistency in network lifetime and it also supports large networks. While LEACH is more suitable for networks having less than hundred number of nodes.

***Keywords:*** WSN, LEACH, PEGASIS, VGA, Protocol Comparison, Network Lifetime

## 1. Introduction

The enhancements in the technology lead the wireless communication and electronics to manufacture low power, multifunctional sensor nodes [1]. The typical architecture of wireless sensor node comprises of power source, transceiver, micro-controller, external memory, analog digital converter and sensors. The Wireless Sensor Network is the set of small power energy confined sensor nodes [2], being used widely for different applications like military [1], environmental, medical, home [6], location and movement finding and industrial [7]. The sensor nodes in wireless sensor network communicate via radio waves with other nodes as well as with base station [4]. The deployment of wireless sensor networks nodes is preferably random in most of the cases or in unapproachable places with remote monitoring. Further, sensor nodes may be equipped with the facilities of data aggregation (Data aggregation is the process of combining distributed data into high quality information) and fusion (Data fusion is a method in which different types of data from several sensors, are integrated to increase efficiency or accuracy) which provide the support to transmit partial processed data instead of raw data. On the other hand, WSN has to cope with several bottlenecks like power consumption [1], computation, communication and unreliable readings [5]. Among the mentioned constraints, power consumption requires more attention to prolong the network life span of the wireless sensor network. Thus for WSN, the routing protocols must have the capability to self-organize [1].

The routing protocols for WSN are classified into various categories shown in fig. 1 [8], out of which hierarchical routing category is selected to analyze the impact on the lifetime of the network. Because hierarchical routing protocols utilize the resources in efficient and optimized ways. In this paper three hierarchical WSN routing protocols are selected based on level of scalability and localization (the determination of the geographical locations of sensors). The goal of the paper is to analyze the impact of protocols on network lifetime on the basis of the network size with small network field.

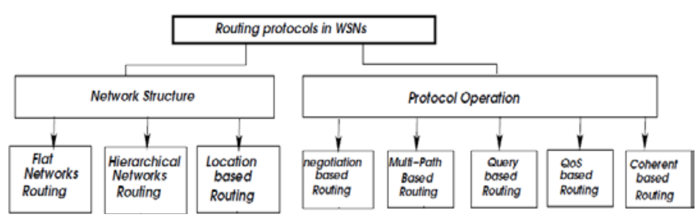


Figure1. Classification of WSN Routing Protocols [8]

may be for sensing events in the vicinity. For routing in location based networks every node is identified by its location. The distance between the nodes can be determined by the strength of incoming signals. The other method to locate the nodes can be the implementation of GPS (Global Positioning System). The negotiation based routing protocols devastate the redundant transmission to the next sensor or BS by accompanying a series of negotiation messages. In multi-path based routing, more than one path is established between source and destination. If the primary path terminates the alternative path will be selected. In query based routing, the destination nodes broadcast a request for sensed data and the nodes having the specified data related to the query transmit back to the node. In QoS-based routing, a balance is maintained between power depletion and data quality: delay, energy, bandwidth, etc. during sending data to the sink. In last, the coherent based routing employs the minimum processing (time stamping, duplicate suppression, etc.) before sending data to the aggregators.

## 2. Selected Protocols

The selected three protocols are LEACH (Low-Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient GAthering in Sensor Information Systems) and VGA (Virtual Grid Architecture).

### 2.1. LEACH

All nodes are organized as set of clusters. Each cluster has a cluster head to communicate with Base Station. The cluster heads are selected on rotation bases to balance the load of energy in the way that most of the nodes get small distances to transmit and only cluster heads are responsible for long transmission to the BS. Besides, LEACH allows data fusion and aggregation in order to minimize the amount of data to be transmitted. Because for energy concerns local computations require less energy than transmitting signals to BS [9] [10].

Each round of LEACH protocol is composed of ‘setup phase’ and ‘steady-state phase’. In setup phase the cluster heads broadcasts an advertisement message to all the nodes to elect cluster head. And the cluster heads are elected depending upon the predefined specified percentage of cluster heads and how many times the node has been elected as cluster head. On receiving the advertisement messages from cluster heads, the non-cluster head nodes decides to which cluster head it will belong depending upon the energy required for transmission to the cluster head. Thus nodes become the members of the cluster requiring low energy transmission for the cluster head [9] [8]. Each non-cluster head node sends a message to the cluster head declaring that it belongs to its cluster after the selection of that cluster head. The cluster head then generates a TDMA schedule for communication with the nodes within its cluster. In steady state phase non-cluster head nodes transmit their data only when their allocated time slots arrive. The radio of each non-cluster head node is kept off all the time except when it is ready to transmit data to BS (when its time slot arrive), reducing the battery power consumption. Furthermore, as the cluster head receives all the data from all the nodes it aggregates and fuses the data to minimize the amount of long distanced transmission with the base station. Thus again reducing the energy consumption. When a node decides to become a cluster head, it also chooses a CDMA code from the available list of spreading codes and informs all the non-cluster head nodes within its cluster about the details of the chosen code. The reason for this is that, the radio transmission of a node with cluster head in a cluster usually affects the transmission in the neighboring clusters. By CDMA, the cluster head filters the received signal using the specific spreading code [9] [8].

### 2.2. PEGASIS

It is chain based architecture in which transmission occurs in such a way that node send and receive data only from the closest neighbor. PEGASIS allows data to be fused but doesn’t support data aggregation. On receiving data, node fuses with its own data and forwards to the next node. Node acting as a chain leader is responsible to communicate with the BS. In each round the chain leader is changed to balance the remaining energy of the network, which in turns results the longer network lifetime of sensor nodes. The chain formation is held by greedy approach which works quite well [12] [8] [10]. Each node selects its nearest node as a neighbor, starting from the farthest node from Base Station. The closest node is assessed by the signal strength from all the nodes in its surroundings. Like LEACH, PEGASIS also choose the chain head (cluster node) randomly for routing to the BS. Each node is chosen as chain head once in every N number of rounds (where N= no. of nodes) [8].

Once the chain is created and chain head is chosen, the chain head of the current round initiates a token for the end node of the chain to start the transmission. Each node except the farthest node of the chain fuses its data with the received data and sends a single packet to the next neighbor. The chain head communicates with BS after receiving the data from each side of the chain and fusing its own data. If a node dies in the chain, the chain will be reconstructed again to bypass the dead node [8].

### 2.3. VGA

It is a GPS-free technique to split the network topology into logically symmetrical, side by side, equal and overlapping frames (grids) [11] [13] [8]. And the transmission is occurred grid by grid [14]. VGA provides the capability to aggregate the data and in-network processing to increase the life span of the network. Data aggregation is done in two steps i.e. first at local level (in grid) and then globally. The nodes that are responsible to aggregate data locally are 'local heads' (grid heads) and the nodes 'global heads' have to aggregate data received from local heads [8] [14]. After the formation of logical grids, election is started in each grid to decide for the local head of the grid based on node the energy and how many times it has been selected as local head. And then the global heads are also selected randomly from the selected local heads. Several local heads may connect to the global head [8] [11]. The local heads are allowed to communicate vertically and horizontally only. Each node within the grid that has the required data will send its data to the local head. Then the local head will aggregate the data and send it to its associated global head that will also aggregate the data again and send it to the BS via other global heads [13]. If a local head or global head dies, a new local/global head is selected after the election [14].

## 3. Related Work

In [5] LEACH, PEGASIS and VGA routing protocols were compared for network lifetime on the basis of transmission range. The experiments showed that the by increasing the transmission range PEGASIS increased the total network life span. LEACH showed longer network lifetime than VGA because of the early death of the sensor nodes. While VGA affects the network connectivity badly but reposts more power when transmission range was increased.

In [15] AODV and DSR were evaluated for performance using normalized routing overhead, PDR (packet delivery ratio) and end to end delay as metrics having the variables pause time and no. of sources. It was concluded that DSR attained the better edges than AODV pertaining to overhead and PDR in restricted conditions. The results also showed that end to end delay for DSR is greater than AODV. Finally implementing large value of pause time enhanced the performance of DSR and AODV protocols.

In [16] the rate of mobilization, pace of location change and routing overhead were used as matrices. The derived results expatiated that DSR performed well for all rates of mobilization and pace to change location even of being accountable to increase the source routing overhead. AODV also achieved the same level of performance in addition to decrease the source routing overhead but is much more costly for high rates of mobilization than DSR. At last, DSDV could not attain the performance comparable to AODV and DSR when the power for transmission is amplified. Nevertheless the routing load of AODV is also boosted.

In [17] TinyAODV (AODV version for WSN), MultiHopRouter (algorithm for OSPF), GF-RSSI and GF are the 4 protocols that were analyzed claiming PDR and the energy consumption as the metrics. The results were evaluated which described that the GF-RSSI generated high packet delivery ratio and reduced power utilization. The performance of the metrics for MultiHopRouter was disgraced as the data rates were increased. Finally, high power consumption was examined in the case of TinyAODV.

In [19] the two different mobility models; constrained mobility (CM) and attenuation factor (AF) were the constituents of the experiment. The simulations for the real environment were based on the 3 matrices; packet delivery latency, packet delivery ratio and routing overhead. The results for indoor environment showed that the simplicity in the mobility models do not cause any change for DSDV contrary to DSR. Further different protocols do not produce pure results in certain scenarios as for the network of 20 nodes; mobility models did not affect the performance of DSR. But for 50 nodes network, mobility models had the impacts on the performance of DSR. Finally, the author suggested that for reliable simulations more work must be done on realistic models.

In this paper LEACH, PEGASIS and VGA routing protocols were compared for network lifetime on the basis of network size in small network field contrary to [5] in which network lifetime was assessed by changing transmission range. Further AODV, DSDV and DSR work in ad-hoc networks while TinyAODV is the version of AODV for WSN and is not hierarchical as for transmission it broadcasts the packets.

## 4. Simulation Scenarios

For all scenarios the common parameters for simulation include the standard values i.e. initial energy of 0.5 joules for each node, first energy model, transmission range of 15 m (except for PEGASIS which is 56.56854 m), random topology of sensor nodes deployment, network bandwidth of 5000 b/s with transmission speed of 100 b/s, data packet size of 2000 b with data processing delay of 0.1 ms, control packet size of 248 b and sensing cycle of 1 sec. The other common parameters are network field of 40 × 40 m2 with 1 BS located at (140, 25), homogenous (having same level of initial energy for all nodes) type for temperature detection, Besides, each protocol was tested for 60, 90 and 120 nodes with both 8 m and 12 m sensing ranges to evaluate the performance of protocols for small (60 nodes) and larger (90 and 120 nodes) networks. The sensing range of 12 m (standard value is 8 m) is selected to analyze the impact of protocols on energy by increasing the sensing area of the sensors. The metric for which the simulation is conducted is 'Loss of Network Connectivity or Network Lifetime'.

## 5. Results

The cumulative results of the whole experiment are shown figure 2. The figure describes the number of rounds for each protocol against the sensing range (i.e. 12 m and 8 m).

Table 1: STANDARD Deviation of each protocol

| **No. of Nodes** | **60** | | **90** | | **120** | |
|---|---|---|---|---|---|---|
| **Sensing Range** | ***12 m*** | ***8 m*** | ***12m*** | ***8m*** | ***12m*** | ***8m*** |
| *LEACH* | 37.86 | 28.44 | 74.45 | 60.50 | 20.82 | 32.69 |
| PEGASIS | 18.96 | 13.11 | 27.47 | 9.59 | 14.81 | 29.88 |
| *VGA* | 30.57 | 33.60 | 15.73 | 120.28 | 99.41 | 26.73 |

The above table I. depicts the standard deviation of 5 repetitions for network lifetime of each protocol in each scenario.

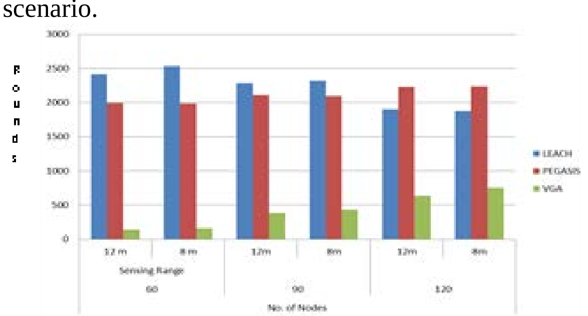


Figure 2. : Network Lifetime for 60, 90 and 120 Nodes

It is clearly evident from figure 2 that for 60 nodes, total network lifetime of LEACH is much longer than the other protocols. This is because LEACH architecture provides the support to reduce the transmission cost for less number of nodes. On the other hand the total network lifetime of PEGASIS is much higher than VGA. The overheads for grid establishment and the selection of local and global aggregators in VGA are higher. This results in the high energy consumption leading to the shorter network lifetime of VGA. In case of the 90 nodes it can be observed that LEACH protocol still remains at the top for higher total network lifetime for both sensing ranges. While in the case of PEGASIS the total network lifetime has been improved and approaching to the total network lifetime of LEACH. For VGA's total network lifetime is again much shorter among the three WSN hierarchical routing protocols due to the increase in overhead. Finally, for 120 nodes PEGASIS achieves the highest performance among the three protocols. The simulation shows that LEACH works well for less than 100 nodes. As the number of nodes increases, the overhead of cluster formation, cluster head selection and scheduling in each round also increase substantially affecting the network lifetime. While on the other hand PEGASIS has the ability to support large networks with longer network life. The reason for this is that PEGASIS creates chain only in the beginning or when a node dies, contrary to LEACH. The VGA is still far behind pertaining to network lifetime.

## 6. Conclusion

The growing pace of technology has opened the way to monitor and control the environment where the human interaction was not easy or even impossible. Wireless Sensor Networks usually do not require any physical interaction for maintenance and controlling that is why sensor networks are getting higher demand for future system monitoring and controlling. For WSN the main constraint is the efficient power consumption which is the great obstacle for performing tasks continuously. For this reason several techniques and architectures have been described, out of which one is the use of efficient protocol which can reduce the power consumption during communication to prolong the network life time. That is because of the fact that the communication is much expensive in terms of energy consumption as compared to the processing.

In this research, three Wireless Sensor Networks protocols (LEACH, PEGASIS and VGA) are compared to find out the performance pertaining to network life time. All the three protocols are classified as hierarchical which makes them to operate more efficiently than previous techniques like flooding. Though wireless sensor networks do not have static topologies and infrastructures but the support for dynamic hierarchy lets these protocols to work longer. While being hierarchical all the protocols have different architectures due to which their performances vary.

The three hierarchical protocols are compared for network lifetime by changing the sensing range of the sensor nodes and increasing the size of network.

The clustering architecture of LEACH makes it possible to reduce the transmission by data aggregation which minimizes the number of packets to be transmitted. Experiment showed that the performance of LEACH is much superior for smaller network (i.e. less than 100 nodes) as compared to PEGASIS and VGA. PEGASIS has shown some consistency in network lifetime for all scenarios and the ability to support large networks. It is also concluded that VGA has huge overhead and the rapid energy depleted regions in the network results in increasing the transmission path and decreases network lifetime.

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