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Comparative analysis of proactive & reactive protocols for cluster based routing algorithms in WSNs

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ABSTRACT

Wireless Sensor Networks (WSNs) are networks that consist of sensors which are randomly deployed in inaccessible area to gathering data and transfer it to user or base station. The most important matters considered in sensor networks are efficient utilization of energy, network lifetime, and environmental conditions changes. To provide the communication facilities within the network a routing protocol is used. There are many techniques used to route data in sensor networks, clustering based is one of most common techniques used, cluster based routing protocols can be classified to proactive and reactive protocol depending on how source finds a route to destination. This paper is aim to study and compare the two mechanisms in cluster based routing by discuss different characteristics in each mechanism, and also analyzed the performance of two mechanisms by take two exemplar protocols LEACH and TEEN from proactive and reactive mechanism respectively in order to compare the performance in same scenario and simulation parameters.

***Keywords*:** WSNs, Sensors, Energy, Routing protocol, Clustering based, Proactive, Reactive, LEACH, TEEN

1. INTRODUCTION

Recent evolution in micro-sensors is come true as result of growth in micro-electro-mechanical systems (MEMS), highly integrated, and low power digital electronics. Micro-

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sensors are tiny, with limited ability to process data and computing resources, and also they are cheap compared to traditional sensors. These sensor nodes together forms a wireless sensor network and sense, measure, and gather information from the environment, and based on some local decision process, they can transmit the sensed data to the user. Smart sensor nodes are low power devices equipped with one or more sensors, a processor, a memory, a power supply, a radio, and an actuator. Sensor node attached with variety types of sensors has ability to sense different types of data, thermal, biological, chemical, mechanical, or information's about nature from different environments. The main characteristics of sensor nodes is limited memory and energy, those sensors are typically distributed in inaccessible areas, and they use radio frequencies to transmit data to base station or desired sink through wireless medium.

Basic features of sensor networks are:

- Self-organizing capabilities.
- Short-range broadcast communication and multi-hop routing.
- Dense deployment and cooperative effort of sensor nodes.
- Frequently changing topology due to fading and node failures.
- Limitations in energy, transmit power, memory, and computing power.

These features, in particular the last three one, make the variance of sensor networks from other wireless ad-hoc or mesh networks [1].

Sensors are usually deployed randomly in inaccessible zone; if one of the sensors consumes its energy, replacing the power supply becomes difficult or impossible in some environments, and energy holes emerge. Moreover, the energy of sensor nodes goes down during the transmission of data. Therefore, routing is an important factor in WSNs, and proper selection of effective routing protocols can preserve energy and prolong network lifetime [2].

Many protocols have been introduced to reduce the power consumption in WSNs. These protocols follow several techniques in routing data, such as low duty cycle, contention based, schedule based or cluster algorithms. Cluster algorithms is one of most common routing techniques used in WSNs, it surpassed with several benefits like increasing scalability and prolong network lifetime. There are two kinds of clustering schemes. The clustering algorithms applied in homogeneous networks are called homogeneous schemes, and the clustering algorithms applied in heterogeneous networks are referred to as heterogeneous clustering schemes [3].

The remainder of the paper is organized as follows. In Section 2, we briefly review related work. Section 3, is shed a light on routing techniques in WSNs and focus on cluster based routing technique. Section 4, shows simulation parameters used in performance analysis comparison between exemplar reactive and proactive protocols. In section 5 the results are discussed. Finally Section 6 concluding remarks are introduced.

2. RELATED WORKS

In [4] Amit K. Kaushik studied and evaluates two different type of routing strategies used in wireless sensor networks i.e. proactive and reactive routing mechanisms. By studied different routing protocols which use these routing mechanisms and have compared them. The study also takes in consideration the homogenous and heterogeneous type of networks and also sees the effect of homogeneity and heterogeneity on the routing in the network.

They take LEACH and SEP routing protocols for homogenous and heterogeneous network respectively using proactive mechanism for routing, and TEEN and TADEEC protocols for homogenous and heterogeneous using reactive mechanisms. Lastly they compared performance analysis of two strategies in term of stability period, lifetime of the network and throughput i.e. data send to the base station per unit round.

In [5] S. Saidarao and R.A.R Chandra Sekhar discussed routing protocols of network and clustering techniques of routing protocols under proactive and reactive classification. The classification of routing protocols introduces by them branched to: Centric routing protocols classified as node centric, data centric and geo-centric (location centric), Nature wise protocols classified as Proactive, Active and Hybrid, and Sensor network type classified as flat routing and hierarchal routing. The exemplar's of proactive and reactive protocols discussed in their study consist DSDV, WRP, and OLSR protocols under proactive mechanism for routing, and consist AODV, DSR, TORA, and ABR under reactive mechanism for routing.

In [6] Divya Bandral and Reena Aggarwal introduces a comparative analysis of routing protocols in MANETs between Proactive, Reactive and Hybrid mechanisms for improving quality of services. They introduced categorization of routing protocols include: Routing Information Update Mechanism, Use of Temporal Information for Routing, Routing Topology, and Utilization of Specific Resources. Their comparison study focused on Routing Information Update Mechanism classification. The exemplars of routing protocols used in comparison between proactive, reactive, and hydride respectively are DSDV, AODV, and ZRP protocol.

In [7] Muthana et. al. introduces a comparative study of MANETs routing protocols, the classification of routing protocols introduces by them branched to: proactive, reactive, and geographical routing protocols. They perform a comparative study by comparing the characteristics and operations, as well as the strength and weaknesses of exemplar's protocols chosen from any categorize, from proactive mechanism the study chose OLSR, WRP, and DSDV protocols, and from reactive mechanism ABR, AODV, and TORA protocols are chosen, as well as from geographical mechanism GPSR, LAR, and GSR are chosen and a comparative study performed between them.

3. CLUSTER BASED ROUTING IN WSNs

Broadcasting data packets takes a place in multi-hop data transmission due to many challenges, the limitation in transmission and computation ability, and high density of sensor nodes through certain area. For this reason routing in wireless sensor networks has been a focus of attenuation in most recent researches in the past few years. The sensor nodes run on non-rechargeable batteries, so along with efficient routing the network should be energy efficient with efficient utilization of their sources and hence this is an important research concern [8].

Routing in WSNs can be divided as shown in Figure 1 into flat-based routing in which all nodes are typically assigned equal roles or functionality, hierarchical-based routing in which nodes will play different roles in the network, and location-based routing in which sensor nodes positions are exploited to route data in the network. This classification of routing techniques is come depending on the network structure.

Hierarchal networks routing protocols can be classified to proactive and reactive protocol depending on how source finds a route to destination. Also classified to homogeneous and heterogeneous protocol depending on nodes/link homogeneity, in other expression all sensor

nodes having equal capacity in terms of computation, communication, and power. This paper will focus on how source finds a route to destination and introduce comparison between proactive and reactive cluster based protocols.

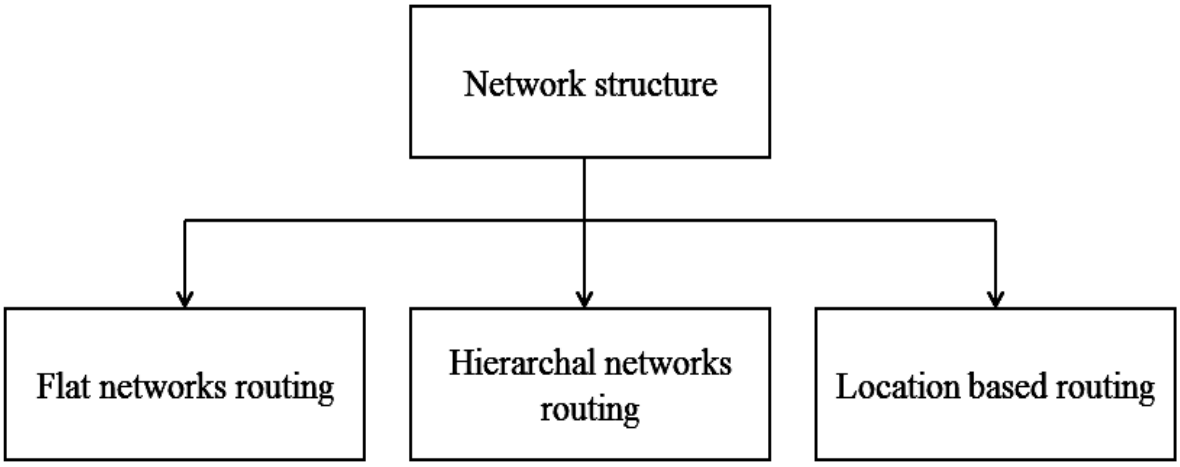

Figure 1. Routing protocols in WSNs: A taxonomy

3. 1. Proactive routing protocols

Also called a table driven approach, it follows a static route throughout the lifetime. In proactive protocols, each node keeps routing information for whole nodes in network in individual routing table. The routing table information's are consistent and current up to date, the update is permanent by sending control messages periodically between all nodes in network to update their routing tables.

The proactive routing protocols use link-state routing algorithms which frequently flood the link information about its neighbor's. The main drawback of proactive routing protocol is that all the nodes in the network always require keeping their routing table up to date and this cause overwhelming in control messages.

3. 1. 1. LEACH

Low-Energy Adaptive Clustering Hierarchy protocol [9] is the first hierarchical or clustering-based protocol in which cluster heads are randomly selected, it is self-adaptive and self-organized, it uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. In LEACH Protocol nodes are randomly distributed in the field with capability of gathering and processing the data. LEACH protocol proceeds into several rounds which are further divided into two phases as setup phase and steady state phase.

LEACH is completely distributed approach and it is a powerful and simple routing protocol, but it go through many drawbacks, Selection of CH in any round is random and does not consider energy level of node, which can lead to drainage of a particular node [10] and it assume the sensor networks are homogeneous networks and These led to perform poorly in heterogeneous environments [3].

3. 1. 2. DEEC

Distributed energy-efficient clustering algorithm [3] is proposed to adapt with multi-level heterogeneous networks, it is cluster-based algorithm in which cluster heads are selected on the basis of probability of ratio of residual energy of each node in network after certain round and average energy of the overall network. In this algorithm, nodes having highest energy has more chances to become a cluster head. It prolongs the lifetime of the network.

3. 1. 3. EEPSC

Energy-Efficient Protocol with Static Clustering [11] is hierarchical with static clustering routing. It does partitioning of entire network into few static clusters to eliminate the overhead of dynamic clustering and tries to distribute the load among by choosing high energy sensor nods as CHs.

3. 2. Reactive routing protocols

Also called on demand approach, the rout decisions based on the present network conditions, so, it dynamically changes the route path. In Reactive routing protocols, when a source wants to transmit packets to desired sink, to find the route to the sink it need to invoke route discovery mechanisms. The route remains valid unless the sink is unreachable or the route is no longer needed. Unlike other approach, all nodes not require to keep routing information up to date.

3. 2. 1. TEEN

Threshold sensitive Energy Efficient sensor Network protocol [12] it follows a hierarchical algorithm with the use of a data-centric mechanism. In TEEN, the cluster head broadcasts two thresholds to its members for sensed operations, hard and soft thresholds. TEEN is performing poorly in applications that require periodic reports, since the user may not obtain any data at all if the thresholds are not attained.

3. 2. 2. EECED

Energy Efficient Clustering Algorithm for Event-Driven Wireless Sensor Networks protocol [13] it enhances lifetime by balancing the energy usage of node. Base station is located in the center of area and is capable of processing messages with enough memory. Data is transferred from nodes to CHs only when an event occurs.

3. 2. 3. Q-LEACH

In [14] an energy efficient algorithm based on quadrant based directional routing protocol called as Q-LEACH introduced which divides the whole network into quadrants. Those nodes which are nearby the sink node will broadcast the message. Since it uses a reactive routing mechanism and hence all nodes maintain the destination node information before finding the path to destination or sink node.

It contains advantage of both location and hierarchical based routing protocols. This protocol uses route request packet to find the path to destination.

Table 1. Comparison between proactive and reactive routing protocols.

Parameters	Proactive	Reactive
Availability of route	Always available	Determined when needed
Control traffic volume	Usually high	Lower than proactive routing protocols
Periodic updates	Yes, some may use conditional	Not required. Some nodes may require periodic beacons.
Route acquisition delay	Low	High
Storage requirements	High	Depends on the number of routes kept or required. Usually lower than proactive protocols
Bandwidth requirements	High	Low
Power requirements	High	Low
Handling effect of mobility	Occur at fixed intervals and alters periodic updates based on mobility	Usually updates Associativity-Based Routing introduced localized broadcast query.
Routing information	Stored in routing table	Doesn't stored
Scalability	Nearly up to 150 nodes	Higher than proactive
Periodic message	required	Not required
Drawbacks	Convergence time is low, routing information flooded in whole network, Unsuitable for reconfigurable wireless ad-hoc network environment and not suitable for large networks.	Routes are not up to date, large delay, more packet dropping, Flooding can lead to network clogging.
Benefits	Rapid establishment of routes, routing information is updated periodically, Control traffic are constant, and routes are always available.	Don't exchange routing table periodically, loop free, Reduce the overheads because it does not need to maintain up-to-date information about the network.

4. SIMULATION PARAMETERS

In this section, the performance of proactive and reactive routing mechanisms are compared, the performance evaluation elects two exemplar protocols from two mechanisms, for equivalence in comparison, LEACH protocol is elected from proactive mechanism, LEACH protocol in basis is designed for homogeneous networks. The performance evaluation also elects TEEN protocol from reactive mechanism, it also designed to adapt with homogeneous networks. Wireless sensor network (WSN) environment in 100 × 100m field in which the base station is fixed at the centre of field with 100 nodes distributed randomly simulated in Matlab platform and the simulation time defined with 2000 rounds to compare the performance of LEACH and TEEN protocols, the word "performance" here implies:-

- Dead and live nodes.
- Packets transferred to cluster heads.
- Packets transferred to base station.
- Number of clusters formed at every round.

Then the performances of these routing approaches are carried out for same scenario and parameters in order to compare and the relationship between them is revealed. The Table 2 shows the simulation parameters used:

Table 2. Simulation Parameters

Parameter	Value
Network field	100,100
Number of Nodes	100
Message size	4000 bits
E_o	0.5 J
E_{elec}	50 nJ/bits
E_{Tx}	50 nJ/bits
E_{Rx}	50 nJ/bits
E_{fs}	10 nJ/bit/m^2
E_{amp}	0.013 pJ/bit/m^4
E_{DA}	5 nJ/bit/signal
P_{opt}	0.1

5. RESULTS AND DESCUSSIONS

With references to parameter set given in Table 2, the result of comparison simulated and discussion illustrated as follow:

Dead and live nodes: From the Figure 2, it is quite clear that TEEN perform much better than LEACH, as in prolonging network life time. X-axis in figure define number of rounds and Y-axis define number of nodes, it is quite clear that while nodes beginning to die in LEACH at early rounds, the first node die in TEEN approximately at round 1200, additionally while all nodes die in LEACH before ending all rounds simulated, TEEN keep many nodes in a live at the end of rounds approximately 19 nodes at a live, so TEEN has better performance in prolonging network lifetime.

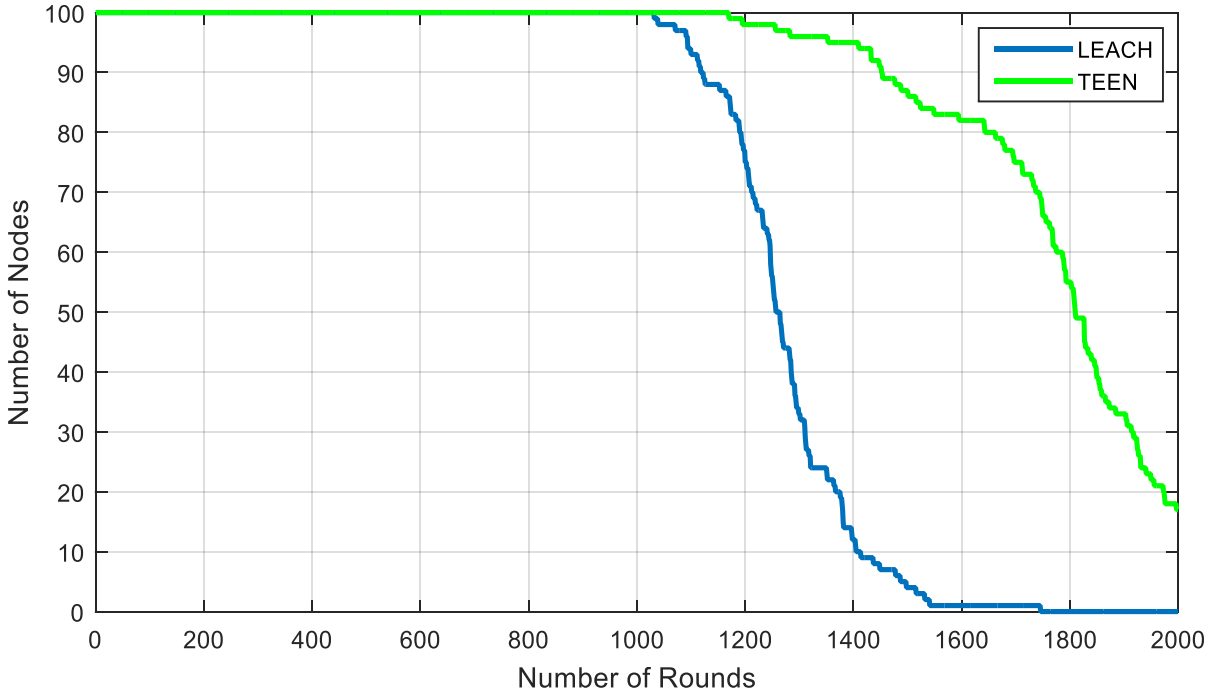

Figure 2. Dead and Live Nodes

Packets transferred to cluster heads: Figure 3 shows messages transferred to cluster heads per rounds, where X-axis define number of rounds simulated, Y-axis define messages transferred per rounds in bit. it is quite clear that TEEN has highest rate in transferring data to cluster heads, and LEACH has the lowest rate, LEACH rate is decreased compared to TEEN for two reasons, first is the number of clusters formed through every round in TEEN protocol is higher than LEACH as shown in the rest of results, so the increasing in number of clusters led to increase the overall packets transferred to cluster heads through network. Second is the decreasing in energy consumption in TEEN protocol compared with LEACH, this led to keep more nodes in live and this guarantees continuity in forming clusters and transferring data through all rounds, so TEEN protocol has highest rate in transferring data to cluster heads.

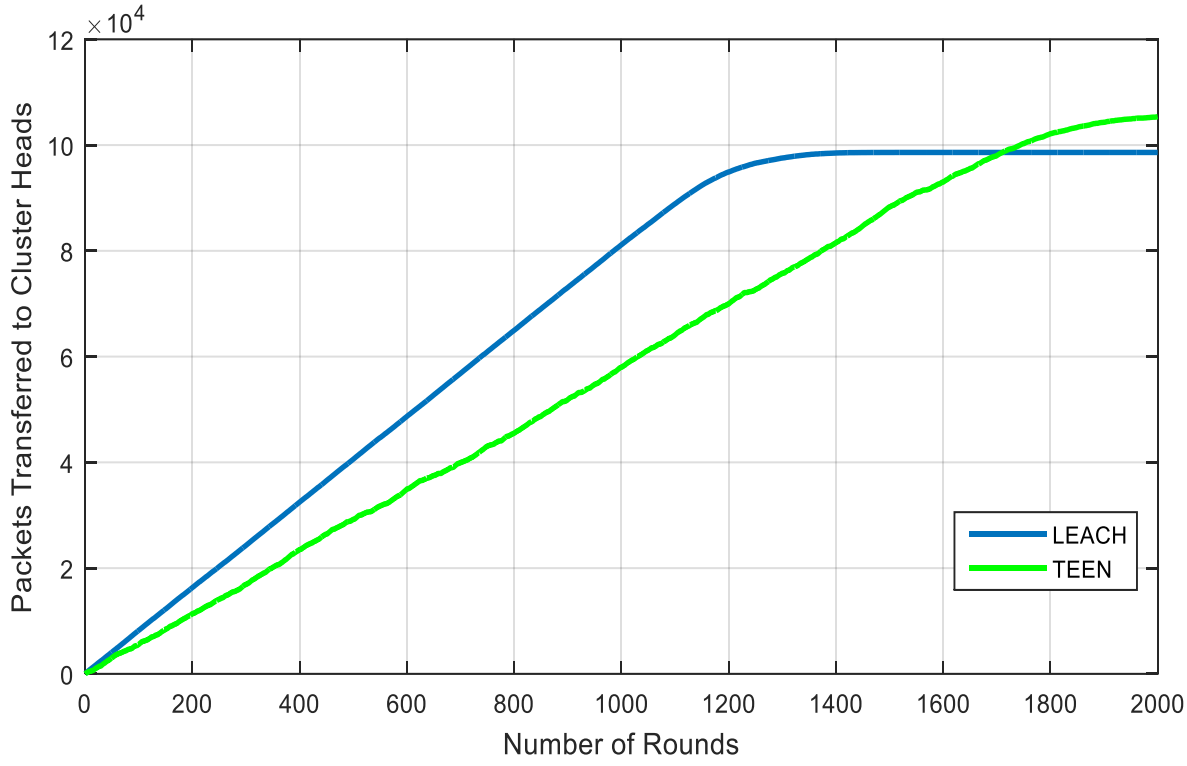

Figure 3. Packets Transferred to Cluster Heads

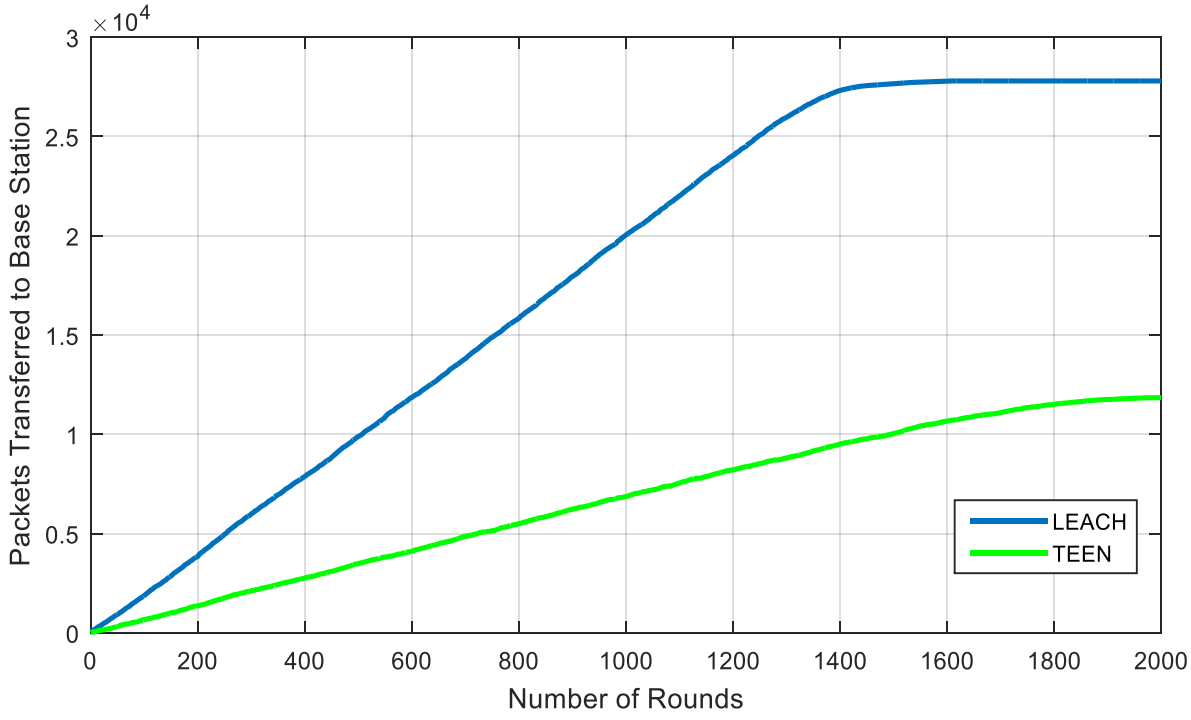

Figure 4. Packets Transferred to Base Station

Packets transferred to base station: Figure 4 shows messages transferred to base station per rounds, in other expression it describe the overall throughput of network, where X-axis define number of rounds simulated Y-axis define messages transferred per rounds in bit. It is quite clear that LEACH has highest data rate in transferring data to base station compared with TEEN, although TEEN transfers more packets to cluster heads than LEACH as shown in figure 3, This preference is coming because of simple reason, the proactive nature of LEACH protocol presupposes the continuity in sensing data from environment and transfer it to base station without delay in rout acquisition as in reactive protocols, in proactive approach the rout is always are available. So LEACH has better performance in increasing network throughput.

Number of clusters formed at every round: Figure 5 shows number of cluster heads formed over all rounds in simulation, it is quite clear while the number of clusters in LEACH protocol begin with considered number of cluster heads, this number is go to reduction with advanced in rounds and be equal with zero approximately at round 1600 as shown due to power depletion in nodes, contrariwise the number of clusters in TEEN protocol begin with multiplied number than in LEACH and go in regular rate and go on until over all rounds in simulation end up.

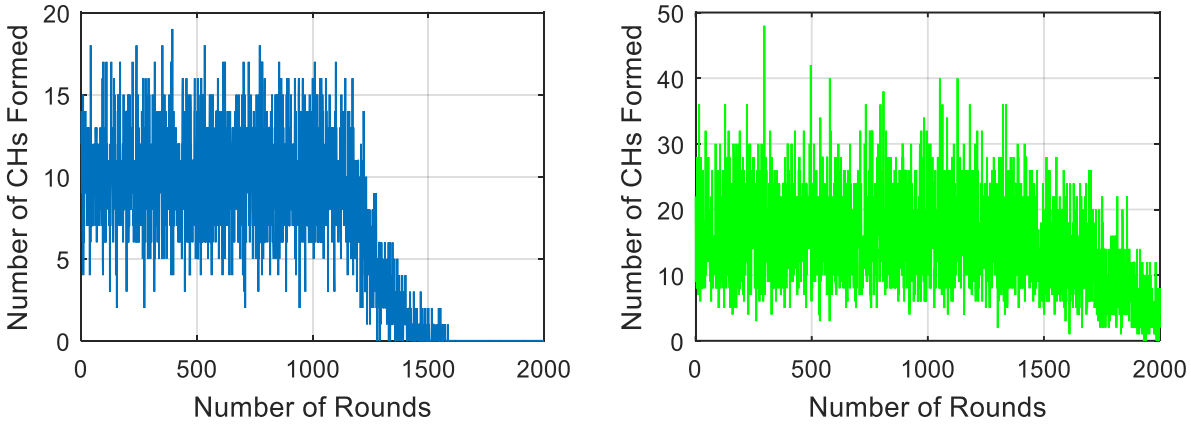

Figure 5. Number of Clusters Formed at Every Round

6. CONCLUSION

In this paper comparison between proactive and reactive routing protocols in cluster technique are introduced. In proactive protocols, each node maintains individual routing table containing routing information for every node in the network, while in reactive protocols nodes collect information about network nodes only when needed. So, the proactive mechanism preferred in applications that require nodes can quickly obtain the route with no delay and quickly establish a session because of route is always available in proactive protocols contrariwise of reactive one that work on demand. In other hand reactive mechanism preferred in applications with low bandwidth requirement and low power consumption because of control traffic volume in reactive protocols is lower than proactive ones. Due to lots of issues in routing protocols of WSNs there is lots of future scope in this direction, as design of cluster routing

protocols combine benefits of proactive and reactive mechanisms and take in consideration security process, most cluster protocols did not consider security in their process.

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