A Clustering based WSN Routing Protocol for Smart Home Applications to Improve Network Lifetime and Emergency Routing

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Abstract
Smart Homes are growing these days as an emerging technology. It integrates multiple modern techniques to improve and provide quality life. Wireless sensor network plays critical role to achieve these objectives. WSN have some challenges associated with this application area like limited source of battery energy, Nodes Deployment, Data extraction and Data transmission etc. This study focuses on data transmission challenge related with smart homes. Routing protocols are used for data transmission which is further categorized into flat routing protocols and clustering routing protocols. Existing research showed that cluster based routing protocols have lot of contributions in efficient data transmission but still there is space for improvement in smart home applications. Based on gap analysis after literature review a Smart Home Routing Protocol (SHRP) is proposed for improved network lifetime and emergency routing to avoid sudden network failure. SHRP is compared with MOD-LEACH, DEEC and DDEEC protocols, and simulation result shows that SHRP have 65% dead nodes, 35% live nodes after completing all rounds which is 65%, 21% and 13.5% improved in terms of dead nodes and 35%, 22% and 14% improved in terms of alive nodes in MOD-LEACH, DEEC and DDEEC protocols respectively.

Keywords:
Wireless Sensor Network, Clustering, Routing

1. Introduction

The recent advancement in wireless communication technologies and Micro Electro Mechanical System, (MEMS) technologies, Wireless sensor network (WSN) is emerging as an attractive application areas like disaster management, smart homes, smart cities, surveillance, medical and health automation and military applications etc.[1]. Wireless and sensor networks has made possible to make connection between human society, computing world and physical world. In general Wireless sensor network have tiny sensor nodes deployed over large area of interest. Wireless sensor networkhas high powerbase stationwhich act as sink and collect all the information transmitted by different sensor nodes deployed in the field. These sensor nodes have limited source of power generally a small battery fitted inside the unit, a small processing unit, sensing unit and a transceiver. To realize these smart home networks, many sensor devices distributed in the house shoulddetect events and send them directly to the base station through the wireless channel.Becausethe sensor devices do not have sufficient computational ability and battery power, an energyefficientsensor routing scheme with low latency, scalability is critical to send information tothe base station.Figure 1 shows an overview of smart home environment. It is clear from the architecture that there are multiple types of sensors are being used in smart home.

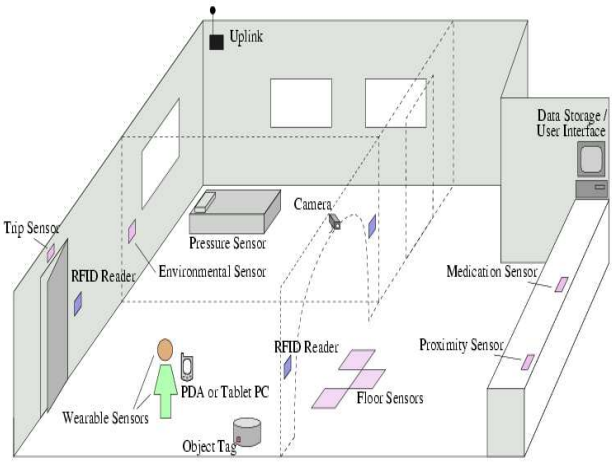

Figure 1: Smart Home Environment [1]

In contrast to conventional Ad-hoc network routing in Wireless sensor network is further challenging because of resource constraints in terms of processing capability, power, transmission range and bandwidth [2]. It is also hard to plan a uniquely identification system like internet protocol we use in our conventional networks. In Wireless sensor network traditional IP scheme is not applicable due to rapid changes in topology and transmission patterns that results in large communication overheads[1,2]. Following are some key challenges associated with this application area.[3]

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Deployment of node: Deployment of node in wireless sensor network is application specific[1-3]. Nodes can be deployed randomly or deterministic. In deterministic approach nodes are deployed at fixed location and data transmission paths are predefined while in random deployment nodes are scattered which look like an ad hoc network. If the distribution of sensor nodes is not there then optimal clustering is an important challenge. Energy consumption is depended on resultant cluster formation. Usually multi-hop communication approach is adapted because transmission between sensors takes less energy due to short distance between sensors.

***Data Extraction*:** Data extraction depend on the requirement of application[1-3]. There are different approaches used for data extraction. For example data can be extracted after specific interval of time. Sensor transmit the data as per their specific times. The second approach is event driven. In this approach whenever required event occur sensors activate and send this information to the base station. The third approach is query orient, in this approach application generate the query to send the required data. The main aim of these approaches is to use energy wisely. It's not like sensor remain activated and keep sending data all the time. This will result in quickly exhaust of their energy and node die in short time. Routing protocol is highly influenced by data extraction method in context of route calculation.

***Fault tolerance*:** Change in network topology in wireless sensor network is another challenge[1-3]. When node dies due to shortage of energy it result in change in network topology. The challenge is to keep network active and transmission successful. This can be achieve using dynamic routing and adjusting transmission ranges of sensor nodes. It is important to provide redundancy in critical applications.

Scalability: Routing in dense field is another challenge in wireless sensor network[1-3]. Nodes are deployed in hundreds of number so it is important that routing must be efficient in such huge network. Clustering play an important role in providing the scalability in wireless sensor network.

***Mobility of Nodes and Base station**:* Generally nodes and base station are fixed in deployed network. [1-3]Mobility of nodes is important challenges in such application which require real time tracking like in shipment of courier and target tracking in military etc. The continuous change in distance between sensor nodes and base station is important to handle. Clustering play an important role to achieve this objective.

Transmission Media: Traditional challenges like noise fading higher error rate which are associated with wireless medium is also challenge in wireless sensor network[1-3]. The bandwidth which is required for data transmission in wireless sensor network is range from 1 to 100 kb/s. Time division multiple access is an approach which is generally used in wireless sensor network at MAC layer but this use more energy as compared with the carrier sense multiple access. Mapping of this technique in wireless sensor network is a challenge.

***Coverage Area**:* Every sensor node have specific transmission range which cover limited coverage area in wireless sensor network. It is important to take consideration of coverage area at the time of application design [1-3].

2. Literature Review

For effective data transmission in recent past many routing protocols are proposed for WSN.Due to random deployment of sensor nodes it is difficult to re charge the batteries to increase source of energy for long time. So to address this challenge there are many protocols that have been proposed.

Artificial Fish Swarm Optimization (AFSO) based protocol [4] is proposed by song to improve the network lifetime using load balancing technique. Parallel and random search algorithm was proposed in this protocol similar to LEACH but only for data transmission along with the multihop transmission which used by CH only.

Based on CH section another protocol VR-LEACH [5] is proposed by Peng. Election of CH is done as per situation of Cluster Head. Nodes which have higher energy then average is only eligible for CH election. Each round is divided into multiple frames and each frame is divided into multiple time slots. To remove the fluctuation of number of CHs LEACH-B is proposed which use residual energy parameter for CH election[6].

KMMDA algorithm [7] is also used to improve network life time. It is the modification of standard K Means algorithm. In this algorithm mean distance between the sensors nodes is consider as a parameter for the candidate of Cluster Head selection.

Energy Efficient Cluster Formation protocol [8]. It provide longer network lifetime by efficient utilization of energy. Independent decision of each node is considered at the time of cluster formation. Among all nodes only five nodes with maximum energy are allowed to take part in cluster head election. Results shows that this approach use minimum energy during cluster formation which results in low overhead and increase in network lifetime.

ID-LEACH [9] is another protocol designed to achieve energy efficiency. This protocol assign unique ID along with binary number to each individual node.BS can send data to the special node on a single path for unicast. Evaluation results show that it has high energy efficiency and can improve the network lifetime.

Dynamic Hierarchical routing protocol [10] is proposed along with the customized version of SPIN, LEACH and DD algorithms based on the proposed design for smart home networks. In this protocol routing tables have been replace by prime number scheme to uniquely identify the nodes and routing path.

To improve the coverage area in WSN, DEECIC algorithm is proposed [11]. The main aim of the work is to do clustering with minimum set of cluster heads to provide the maximum coverage in the deployed network. Every Sensor node are given a unique ID to access and manipulate it individually as per requirement. Cluster Heads are changed with the time according to the parameter of residual energy set in the algorithm.

LEACH[12] is one of the most famous routing protocol in WSN. In this cluster head is elected among the nodes based on some probability. Nodes rotate the task of becoming CH in each round. This protocol is successful in uniform load distribution across the network but not suitable for many real-time WSN applications because of single of routing.

A chain based protocol, PEGASIS[13] is introduced by Lindsey as an improvement in LEACH protocol by minimizing intracluster communication overhead. Using greedy approach closed chain formation by neighbor nodes is the key idea in this protocol. Data is forwarded to the BS by leader nodes. This protocol is also single hope so it is also not suitable for large scale network applications.

PEZCA[14] is a multihop routing protocol to improve network lifetime by efficient utilization of energy. This protocol is developed based on LEACH and PEGASIS. This protocol divides its network in fan shape area having BS in center. Each area is considered as cluster and data is transmitted to BS by CH to CH communication.

BeamStar[15] is another routing protocol which has the objective to reduce the size and cost of network. To carry out network operation it use the infrastructure provided by an edge base nodes. Directional antenna with different power ranges is available in the region to reach BS in any part of the network. This technique will allow to manage network by BS instead of sensor nodes. Location information can be generated by scanning the network with sector number and ring number. This information is then transmitted to sensor nodes to route the data more efficiently.

BeamStar do not use any clustering technique to reduce energy consumption, this limitations is eliminated by Li and Yang by proposing cluster based BeamStar (CBS)[16]. This protocol is divided in three phases, first phase is locating phase which is done on the same principals of BeamStar. Second phase is cluster formation by making cluster of those nodes which have identical IDs. CH is elected among the nodes which have maximum residual energy. Third phase is data transmission which is done by LEACH principals.

Based on the gap analysis after literature review Smart Home Routing Protocol (SHRP) is proposed. This is anapplication specific protocol which take the advantages of the resources used in home to recharge the batteries for providing continuous supply of energy to some specific nodes. These nodes will play the role of cluster heads. We also introduce the idea of cluster head helper to avoid sudden network failure in case of malfunctioning of cluster heads.

3. Smart Home Routing Protocol (SHRP)

It is evident from the literature review done in previous section that none of the existing protocol took the advantage of smart home environment. Higher Energy consumption is a critical challenge in routing protocols. Sensor nodes consume their energy during sensing of information from their environment, processing the sensed data and data transmission. Data transmission is done from nodes to cluster heads and cluster heads to sink. The main source of energy for nodes in deployment field is their battery supply. Once the battery is drained completely network will goes down. Recharging the battery is not generally not possible in filed but by taking the advantage of home environment this is possible efficiently and effectively. Usually CHs consume their energy during intercluster, intracluster data transmission and data processing. With increase in number of nodes in a cluster its energy consumption rises. Random clustering results in larger size clusters with the increase of network size which leads to connectivity and coverage issue across the network. Random clustering is also created because there is no control of cluster head selection. This election is done in each round with some percentage among the nodes.

To overcome the drawbacks discussed above, Smart Home Routing Protocol (SHRP) is proposed. In this protocol nodes are divided into different regions. Each region has a special node which have rechargeable battery source and will act a pre-defined Cluster Head while other nodes will act as a sensory nodes which sense the information from environment. Among these nodes cluster

head helper (CHH) will be elected if primary CH is dead due to any reason like hardware failure. This CH election will be based on nodes residual energy and distance.

Network is consist of n number of sensor nodes deployed in 100m^2 area having base station in the center for optimal distance and energy utilization. Some assumptions are taken like some sensor nodes have rechargeable battery, nodes do not have GPS, transmission range do not change, network has continuous data stream to transmit it to CH and Sink.SHRPtake advantages of home environment to make sure continuous availability of energy to recharge the battery of sensors. These special sensors is acting as Cluster Heads only. These CHs are not dependent on limited battery supply to stay alive.

In SHRP, the nodes organize themselves into local clusters, with one fixed node acting as the cluster head. This cluster head do not depend on limited source of batter energy rather it have continuous supply of power to recharge its battery. All other nodes transmit their data to the cluster heads, while the cluster head node receives data from all the cluster members and transmits data to the remote Base Station. Therefore, being a cluster head node is much more energy exhaustive than being other nodes. So we proposed fixed cluster head idea to avoid re-election of cluster heads among other nodes of network after complete draining of energy.

The working of Smart Home Routing Protocol (SHRP) is divided into rounds. First round begins with a set-up phase when the clusters are organized by joining their respective cluster heads, trailed by a steady part when data are transferred from the nodes to the cluster head and onto the BS. Remaining all rounds will use the same CH which was elected in the first round. Alive status of CH is continuously check in each round. If primary CH is dead CHH will be elective based on higher residual energy and distance from the BS in a particular zone. Figure 2 shows the SHRP model blocks.

Energy calculation is only applicable at non cluster head. Equation 1 show the mathematical notation of energy calculation assuming distance to the cluster head is normal.

$$E_{non} - CH = lE_{elec} + l \in_{fs} d_{to}^2 CH \qquad \text{(Equation\#1)}$$

In this equation d^2 to CH is distance from node to cluster head.

For transmission and receiving of L bits messages at distance d radio expansion is as per equation 2 & 3 respectively.

$$E_{Tx}(l,d) = E_{Tx} - elec(l) + E_{Tx} - amp(l,d) \quad \text{(Equation\#2)}$$
$$= \{E_{elec} + l \in_{fs} d^2, \quad d < d_o$$
$$= \{E_{elec} + l \in_{fs} d^2, \quad d \geq d_o$$

$$E_{Rx}(l) = E_{Rx} - elec(l) = lE_{elec} \qquad \text{(Equation\#3)}$$

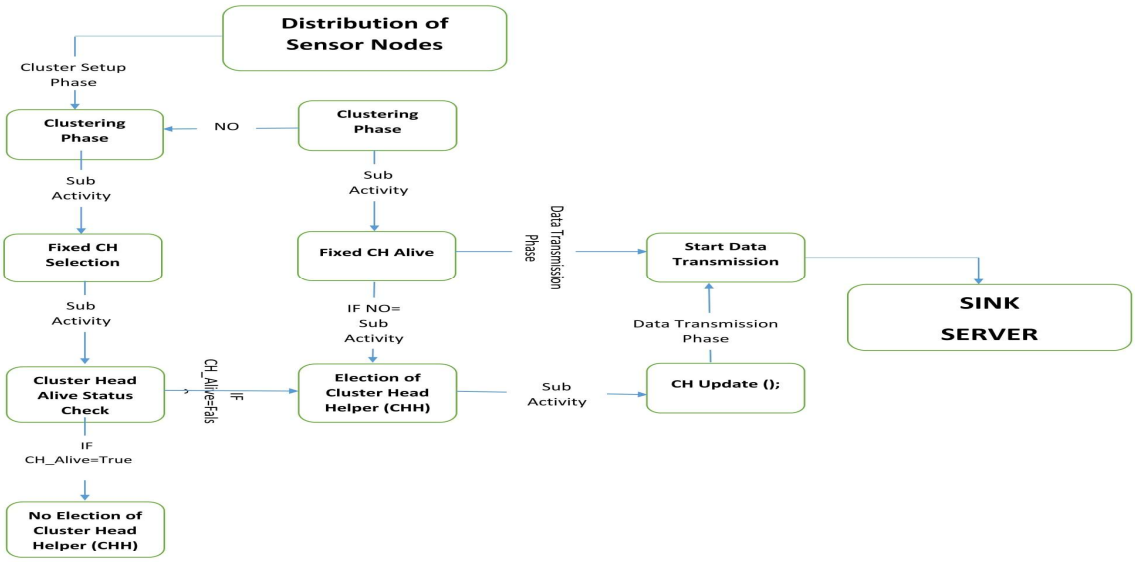

Figure 2: SHRP Model

Smart Home Routing Protocol (SHRP) Steps

1. *Network Initialization and assign unique ID to each node*
2. *Clustering Phase Start*
3. *Nodes join their respective Cluster Heads;*
4. *Data transmission initialized*
5. *Check Fixed CH Alive Status*
6. *If CH Alive Status is true then CHH stay inactive*
7. *If CH Alive Status is false election of CHH && Broadcastupdate message send to nodes to join new CH for data transmission*

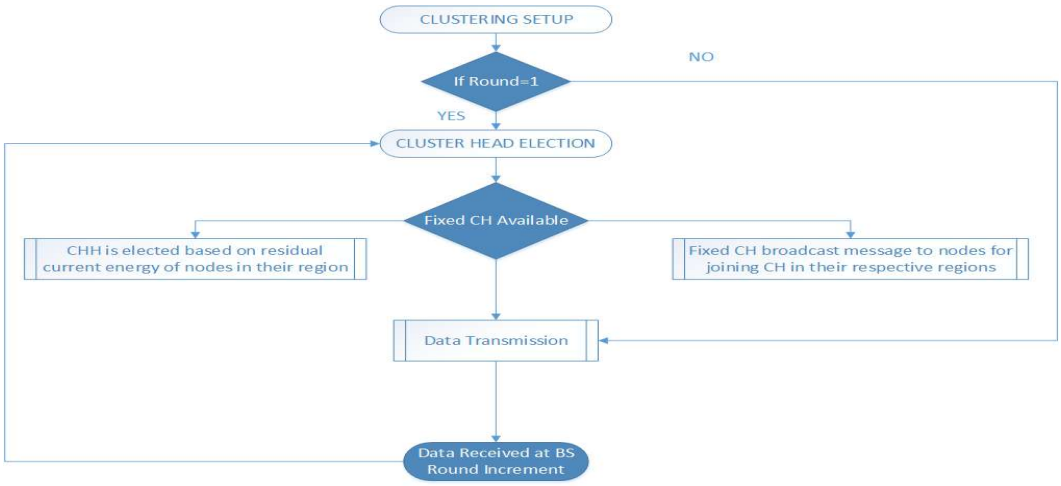

Figure 3: Cluster Setup Phase in SHRP

Figure 3 shows clustering setup phase flow. It depicts that if round is not first then it means cluster is already setup and it jump to the data transmission phase directly because cluster head is already available for data transmission. But if it is the first round than cluster head broadcast message to the nodes to join their respective CHs in their religion. Once data is delivered to the BS this flow continues and no re-election of CHH is required but if CH is dead due to hardware failure or any other reason CHH will be elected among other nodes based on higher residual energy.

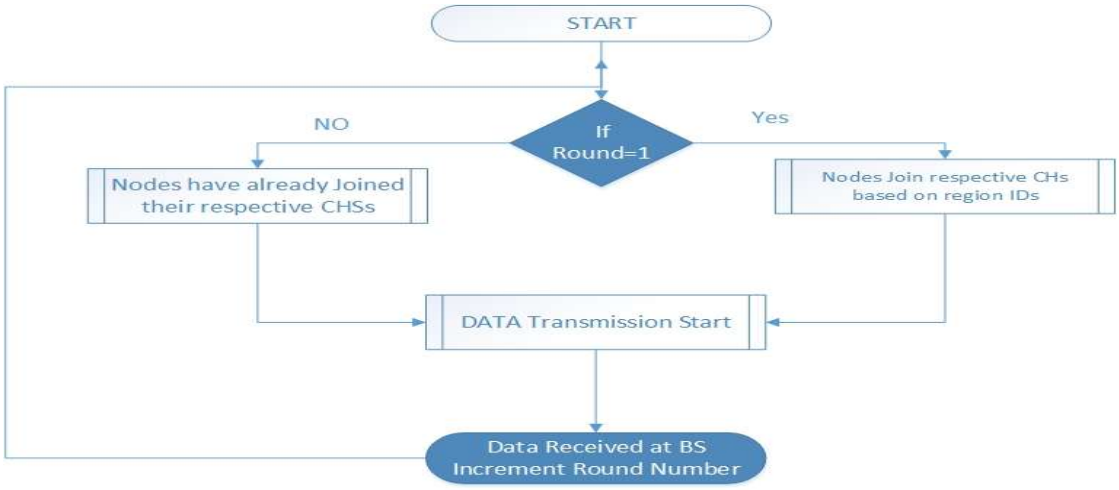

Figure 4: CHH Election in SHRP

Figure 4 shows the flow chart of data transmission. Flow shows that if that if there is first round than nodes must join their respective CHs and then transmission of data starts. Once first round is completed than there is no need to re-join CH again and again as there is no re-election of CHs in SHRP till then it is alive.

4. Results Analysis

The main objective of the SHRP protocol is to improve network lifetime and receiving of more data to BS without any loss in emergency situation which may raise due to CH failure. It is important to consider that the scheme of cluster head helper added a layer of fault tolerance in the network which may cause sudden network failure. SHRP performance is evaluated with MOD-LEACH[17], DEEC[18] and DDEEC[19]. The behaviour of the protocol is compared in terms of dead nodes per round, alive nodes per round, cluster heads per round, packets received to the BS and over all network lifetime.

Table 1 shows the environment setup parameters. Sensor nodes are spread over the area of 100X100m with BS in the centre. Each nodes have 0.2J initial energy.

Table 1: Environment Setup Parameters

Parameters	Values
Area	100x100
Initial Energy	0.2J
Number of Nodes	200
Number of Rounds	1000
Packet size	500bytes
E_{elec} (T_x, R_x)	50nJ/bit
Nodes Deployment	Random
BS location	Centre
Compared with	MOD-LEACH, DEEC and DDEEC
Simulation Tool	MATLAB

MATLAB was used to set this environment. Results showed significant improvement in network life time in normal and as well as emergency routing situation.

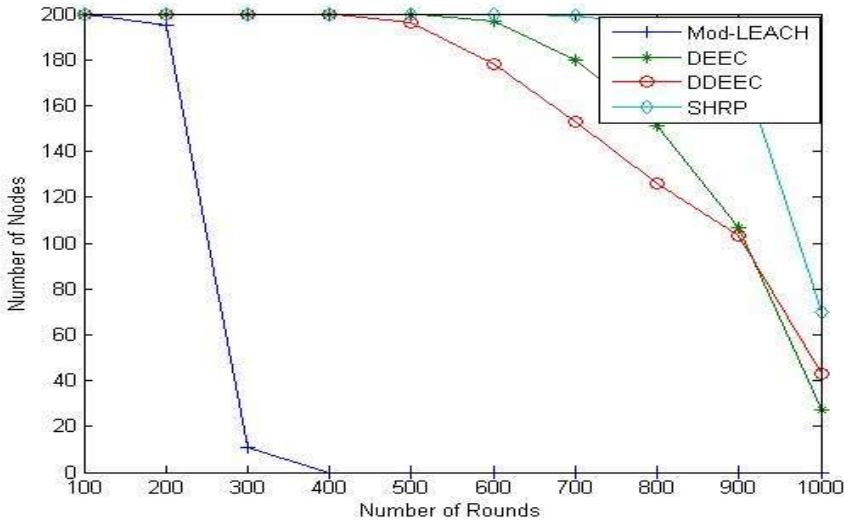

Figure 5: Number of Alive Nodes

Figure 5 shows a number of alive nodes per round. This X axis have number of rounds and Y axis have number of nodes. It can be observed that for MOD LEACH there is no node alive in 300 rounds, while in DEEC, DDEEC and SHRP there are still some Sensor nodes are alive. This is due to optimal energy utilization during data transmission and cluster head selection.

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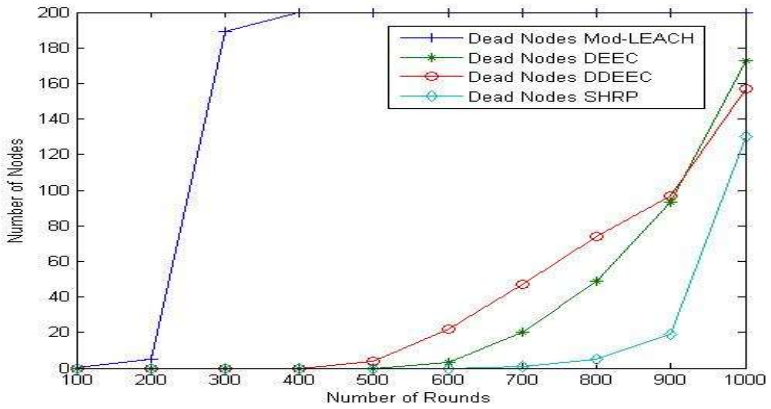

Figure 6: Number of Dead Nodes

Figure 6shows the comparison of number of dead nodes.MOD LEACHhas highest and SHRP has lowest in dead nodes. Graph shows that 100% nodes in MOD LEACH, 86.50% in DEEC, 78.50% in DDEEC and 65% nodes are dead in 1000 rounds. Cluster Heads is another evaluation parameter for SHRP performance evaluation. In SHRP there is fixed cluster head so it is important to make sure these cluster heads will remain stable till the completion of all round. Figure 7 shows that number of cluster heads are stable and consistent in all rounds except in the emergency routing Scenario in which cluster helper is elected. While in other routing protocols there is high fluctuation in number of cluster heads per round. In contrast with these protocols we took the advantage of smart homes we used cluster heads and made them stable in every single round till the completion of maximum rounds.

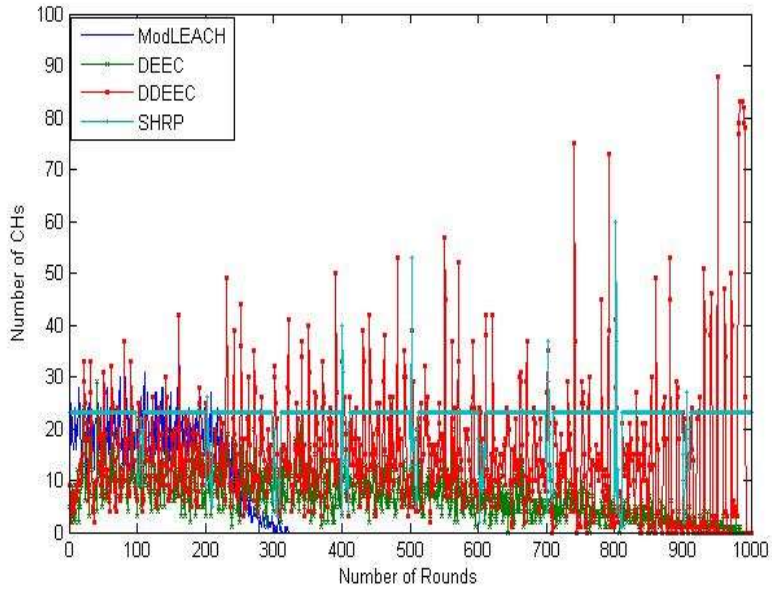

Figure 7: Number of CHs

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Packets received to the base station is high which is evidence of less packet loss as compared to other protocols. Figure 8 shows the number of packets received to the base station sent by cluster heads. Least number of packets received by Mod LEACH.

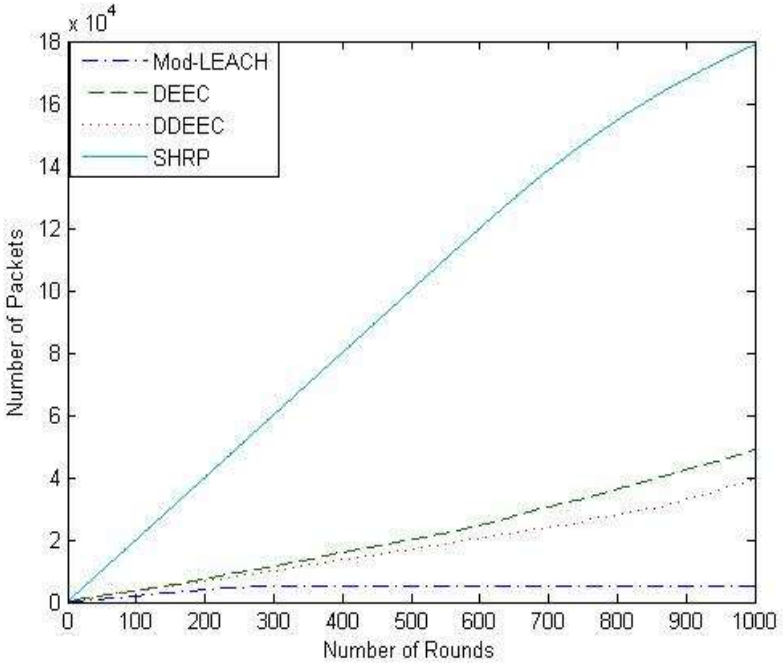

Figure 8: Number of Packets received by BS

Table 2: Simulation Results Summary

Evaluation Parameters	MOD-LEACH	DEEC	DDEEC	SHRP
Alive Nodes	0	27	43	70
Dead Nodes	200	173	157	130
No ofPackets	5111	48908	39533	178860

Summarizing the results in a table 2 shows that SHRP have 65% dead nodes, 35% live nodes after completing all rounds which is 65%, 21% and 13.5% improved in terms of dead nodes and 35%, 22% and 14% improved in terms of alive nodes in MOD-LEACH, DEEC and DDEEC protocols respectively. It can be observed that these parameters eventually play role in improvement of overall network life time which is the primary objective SHRP protocol.

5. Conclusion

It is important to consider the application area while designing the WSN routing protocol because these protocols are tightly coupled with their specific applications. We designed Smart Home Routing Protocol (SHRP) by considering the requirements of smart home environment and we took the advantage to recharge the batteries of Cluster Heads and also took care of emergency routing by implementing the technique of Cluster Head Helper to avoid sudden network failure. Validation results have proved that network life time increase by decreasing the number of dead nodes in SHRP as compared to MOD-LEACH, DEEC, and DDEEC while CHH showed that alternate path is available in case of failure or malfunctioning of cluster heads. CHH technique played an important role in the increase of network life time by avoiding the sudden network fail. The scope of the work does not cover any data processing technique at nodes or cluster heads. In future data processing techniques like can be used at CHs to reduce communication overheads and improve the quality of data which is transmitted to the BS.

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