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A Review on Relay Selection Techniques and Cluster Based Routing Algorithms for Wireless Sensor Network

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Abstract: ***In this paper, we discuss clustering techniques and routing protocols for Wireless sensor Network. We are shortly discussing the operations of those algorithms, and also comparing them on the performance between the assorted schemes. Specifically, we can examine the performance in terms of the ability and quality aspects of those schemes and also examine how these schemes improves the energy utilization of the whole network. We co-jointly discuss enhancements to be created for future projected clustering schemes. This paper offers the reader with a basis for analysis in clustering schemes for Wireless sensor Networks.***

Keywords: Wireless Sensor Network; Relay Selection; Clustering; Topology Management; Energy efficient techniques

1. Introduction

A Wireless Sensor Network is consists of large amount of sensor nodes that are distributed in environment to sense the surrounding area or a targeted area and then transmit the sensed data to the Base Station (BS) or a sink node[1]. Sensor nodes are generally deployed in the area where almost impossible to reach for human beings. Sensor nodes are powered by an external battery and it is very difficult to replace the battery so that reducing the energy consumption is the key issue for the researchers. To reduce the energy consumption of these sensor nodes an energy efficient algorithm or techniques need to be use which not only use nodes energy efficiently but also increases the life time of the whole network [2]. In WSN to achieve scalability and to reduce the energy consumption while transmitting and receiving the information a clustering algorithm can be used [3]. In clustering all the sensor nodes of WSN are grouped together to form clusters. The overall process is completed in two steps. In first step, clusters are formed by the sensor nodes and then a cluster head (CH) is assigned to each cluster [4]. All the member nodes of the cluster send their data to the cluster head directly. In second step, all the data collected by the cluster head is then forwarded to the base station or sink. The main purpose of using clustering is to increase the network lifetime by reducing the number of intermediate nodes that can participate in the transmission process [5].

WSN consist of thousands of nodes these nodes are sensor nodes that sense the data from the atmosphere and after processing that send it to the base station (BS) or sink. Sink may be another node in the network. The components of sensor node in wireless sensor network [6] are power source, sensors, Analog to digital converter, microcontroller and transceiver shown in figure1.

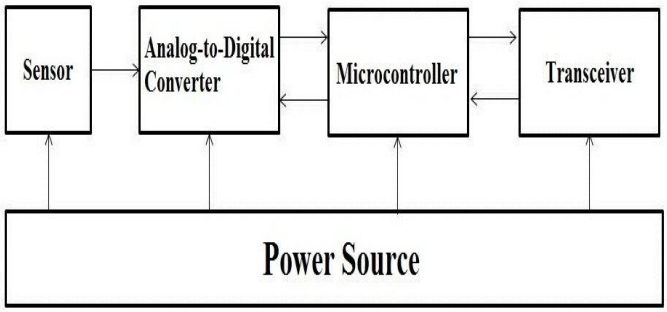

Figure 1: Components of Sensor Node in WSN

The working of these components is discussed below:

Power Source: Sensor nodes in WSN are deployed in the environment where humans can't reach so a battery is used in sensor nodes to provide power to the components of senor nodes [7]. Due to this limited energy of nodes it is necessary to use some energy economical algorithm to reduce the energy consumption of these sensor nodes.

Sensor: Sensor is an electronic device which is used to sense the data from the environment and produce a continuous analog signal corresponding to the sensed data. In sensor node one or more than one sensors can be used to sense the environment. There are many sensors that are used for different number of applications like temperature sensor, humidity sensor and sound sensor etc.

ADC: In sensor nodes Analog-to-Digital converter (ADC) is used to convert the continuous analog signal produced by sensors to a digital form that is in the form of 0's and 1's. The operations performed by ADC are sampling & hold and quantization and encoding.

Microcontroller: In sensor nodes microcontrolleris used to control all the operations performed by the components of sensor nodes [8]. The microcontroller takes data from the ADC which is in digital form so it can be processed easily by microcontroller. After processing the data is sent to the transceiver to transmit it to the desired destination.

Transceiver: In sensor nodes the transceiver works as both transmitter and a receiver. It is used to transmit data to the base station or to the other sensor nodes in the network and in the receiving mode it receives information from the base station or data from the other nodes of the sensor network.

Many clustering algorithms or techniques were designed for WSN but most of these techniques realized that using only one cluster head for transmitting the data of all the sensor nodes might become a bottleneck because sometimes it is loaded with more data as compared to any other node in the network. To increase the life time of the cluster head one can select the cluster head primarily on the basis of their residual energy or by providing more power to the cluster head as compared to the other nodes in the network[9]. The cluster heads of the clusters that are nearer to base station will consume more energy as compared to the cluster heads of the clusters that are far from the base station because all the data is forwarded to the base station so the cluster heads nearer to the base station transmits additional data packets than others so they consume their energy quickly [10]. To overcome this problem and to improve the network performance and lifetime we have to use re-clustering which prevents cluster heads to die that are near to the base station or sink. In re-clustering the role of cluster head is distributed among the cluster members it means that each node of the cluster will become cluster head one by which will increase the life time of the cluster head but sometimes using re-clustering is not a good idea because re-clustering have an effect on all the nodes that become cluster head for the clusters near to the base station [11]. This problem is overcome by reducing the size of clusters that are near to the base station because reducing the size will also reduce the intra cluster load on the cluster heads of that clusters [12].

WSN play an important role in our daily lives and it has many applications. The areas in which we were using wired sensors now we are using wireless sensors due to the advancements in the technology. We depend on wired sensors for years for easy tasks to very complicated tasks such as monitoring the temperature, patients in hospitals etc. [13].

Wireless sensor networks have many applications in different number of fields. In military application it is used for mapping of battle field and to observe targets [14] and in health care applications it is used to monitor the blood pressure and heart beat of the patients and then send information to the concerned doctor. WSNs have endless applications one such example is Smart Dust [15].

Wireless sensor networks are capable to deploy in ad-hoc manner that is the advantage of WSNs [16].Before deploying the sensor nodes into a target area it is impractical to group these sensors because of this reasonlarge amount of research has been done to group these sensors together and form a cluster [17]. In figure 2, we can see deployment of nodes and cluster formation in wireless sensor network.

As shown in figure 2 the nodes in the sensor networks are grouped into 3 clusters each cluster consists of 7 sensor nodes these nodes send their data to the cluster head of their cluster and then this data is forwarded to the base station or sink by cluster heads of all the clusters [9].

- **Sensor Node:** A sensor node is the main element of WSN. A sensor node can perform multiple tasks in the sensor network like sensing, routing, storing information and data processing.

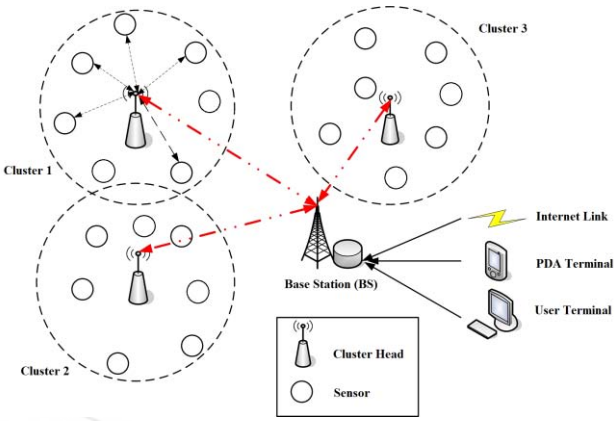

Figure 2: Clustering in WSN

- **Clusters:** In wireless sensor network clusters are the number of sensor nodes grouped together to form an organizational structure [18]. As the WSN consist of large no. of nodes so they need to be divided into clusters to make communication easier and efficient.
- **Cluster head:** Cluster heads are the leader node of the clusters in the wireless sensor network. The function of these cluster heads is to control all the activities in the clusters. They assign a time slot to each member node of cluster to collect data from these nodes. After receiving data from the nodes these cluster heads perform data aggregation and send the gathered data to the base station [19].
- **Base Station:** The base station or sink is the control centre which provides a communication link between the end user and the sensor network and also the data received from the sensor nodes are analysed at the base station [20].
- **End User:** The data sensed by the senor nodes in the wireless sensor network is used for number of applications one can use the information obtained by the sensor network over internet for a particular application by using PDA or computer devices. The end user also produce query in queried sensor network in which a query is sent in the network to gather specified data.
  Clustering techniques plays an important role in grouping the sensor nodes and also improves the performance of the network. In wireless sensor network there are many limitations which we have to take into consideration while using clustering.
- **Limited Energy:** Nodes in the WSN have limited amount of energy which is used to sense data from the environment and send this data to the sink.The sensor nodes are powered with a battery and changing a battery of these nodes is impractical because these sensor nodes are placed in the environment where humans can't reach so it is important to use this limited energy in an efficient way. Proper clustering will reduce the overall energy consumption of the network [21].
- **Network Lifetime:** In WSN the limited energy of the

sensor nodes will also result in the reduced network lifetime. Proper clustering technique will increase the lifetime time of the nodes which also result in increasing the lifetime of the network [22].

- **Limited Abilities**: the small size of the sensor node and limited available energy will also limit the capabilities of sensor node such as communication range, data processing etc. Shared resources can be used by using proper clustering techniques.
- **Application Dependency:** Sometimes a given application of WSN can heavily depend on organization of cluster. While planning a clustering algorithm, algorithm which provides robustness in the application and will adopt the requirements of number of applications should be considered as a good clustering algorithm.

2. Related Work

Efficient Algorithm for Prolonging Network Lifespan of Wireless Sensor Network [23],presents an easy technique for increasing the lifetime of the network and didn't compromise with any of the necessary requirements of the WSN. By using relay nodes or intermediate nodes efficiently the network will work for longer time period.In their work, relay nodes or intermediate nodes are used which forwards the data from the sensor node to the base station or sink. They also calculated the required range of the relay nodes to maintain the successful connectivity in the sensor network and then analyze the effect on lifetime of the network. By using a technique of particle swarm optimization the location of the base station or sink is obtained from the relay nodes. Their result shows that combination of relay nodes and optimal location of the base station or sink will increase the lifetime of the sensor network. Therefore, to increasing the lifetime of the sensor network this technique can be used.

In Energy-Efficiency of Cooperative Communication with Guaranteed E2E Reliability in WSN [24],analyze the CC and SISO transmission techniques in single-hop and multi-hop both. The optimal number of cooperative nodes and the broadcasting bit error rate obtained for the energy efficiency. In harsher environment for long distance communication the cooperative communication is more suitable.The concept of single-hop is then extended to the multi-hop clustered network in which they studied the energy consumption of different number of nodes which includes head node of cluster, cooperative nodes and member nodes of the cluster. They increase the lifetime of the network by adjusting the transmit bit error rate.

In Energy Efficient Data Gathering in Densely Distributed Sensor Network [25], they examine the issues occurred in collection of sensed data that is generate by the densely distributed WSN. Their examination shows that in such network it is necessary to use energy economical big data gathering.Whereas the energy consumption will be reduced by standard mobile sink technique but they lead to number of different challenges like determining the position of sink node and cluster formation before collecting the data. To overcome these issues they presented a new clustering technique named as mobile sink based data collection technique. This technique is based on improved Expectation-Maximization technique also to reduce the energy consumption optimum number of clusters were calculated. To verify the effectiveness of their protocol they present the numerical results.

Achieving Source Location Privacy and Network Lifespan Maximization Through Tree-Based Diversionary Routing in Wireless Sensor Network [26],WSN is gaining popularity these days due to large number of applications in both military and industrial use. However, source location privacy is one important challenge in implementing WSN. They present a tree based diversionary technique to conserve source location privacy by using hide and seek approach to create diversionary routes on the path from the real source node to the sink or base station. The end of every diversionary route is a decoy (fake source node), that periodically emits fake events. Their proposed technique is to increase the lifetime of the sensor network. The main goal is that the lifetime of the sensor network is depends on the nodes which consumes more energy, and then the proposed technique reduces the energy consumption of that nodes and make redundancy diversionary routes in non-hotspot regions with sufficient energy. Hence it achieves both privacy preservation and increased network lifetime. They analyze energy consumption in WSN and give guidance on number of diversionary routes which can be created several regions away from the base station or sink. They also establish an attack against phantom routing which is extensively used for source location privacy protection namely, direction-oriented attack. To know how the direction-oriented attack will be defeated by the proposed techniques they perform a comprehensive analysis. Their result shows that their technique is very effective to enhance the privacy protection while increasing the lifetime of the network.

An Energy and Proximity based Unequal Clustering mechanism for Wireless Sensor Network [27],Presents an Unequal Clustering (EPUC) technique for WSN. EPUC is used to overcome the unequal energy consumption of nodes in the region of the sink or base station due to the increased data relaying activity. In EPUC the selection of cluster head is on the basis of their distance from the base or sink and their remaining energy. The area is divided into tracks centered at the BS and also the number of clusters will increase as we go near to the base station or sink. Nodes having more remaining energy are selected as cluster heads. Simulation result confirms the effectiveness of the proposed EPUC technique in increasing the lifetime of the network, compared with existing schemes.

3. Relay Selection Techniques

It is very hard to select relay or group of relays to improve the overall network performance in WSN in terms of better bit error rate performance, higher data rate/throughput and lower energy consumption. The relay selection should not be based on source to destination it should be based on the overall network performance. A new technique called cooperative relaying in which all the nodes cooperate to improve the quality of communication between two nodes is gaining popularity [28]. In cooperative communication the main idea is of resource sharing to achieve more reliable transmission [29].

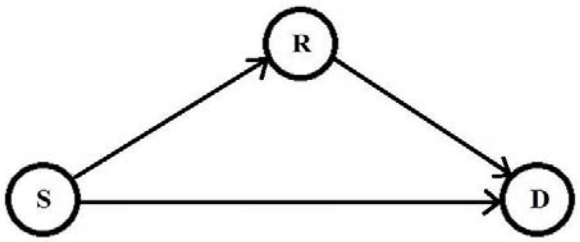

Figure 3: Cooperative Communication

The term Relay channel is used for systems where the relay is a dedicated device which doesn't have its own information to transmit. While the term co-operative communication is used in which relay is another user or node having its own information to transmit so it can act as both a source and a relay. The relay channel has three nodes: source node (S), relay node (R) and destination node (D). The figure 3 shows the cooperative communication. The function of relay node is to assist the source node to forward the information to destination node using different paths [30].

Some of the most commonly used protocols for wireless channel are Amplify and Forward (AF), Decode and Forward (DF) and Compress and Forward (CF).In Amplify and Forward scheme the received signal from the source is amplified by the relay nodes with a gain factor and then forwards the resulting signal to the destination. The destination receives two signals in which one is the signal transmitted by the source and second is the amplified signal transmitted by the relay so it can make better decision [31].

In Decode and Forward scheme the relay node first tries to retrieve the information sent by the source node and then converts it to information bits and re-encodes them and then forwards it to the destination [32].

In Compress and Forward scheme a quantized and compressed version of received signal is transmitted by the relay node therefore, the destination node perform the reception operation by combining both the received messages coming from source node and the relay node [31].

4. Routing Protocols

In this paper we also discuss the routing protocols- PEGASIS, AODV and AOMDV.

• **PEGASIS:** PEGASIS (Power efficient Gathering Sensor Information System) [33],is an extension of LEACH protocol. It is a chain based protocol. In this protocol it is assumed that all the nodes have information about all other nodes in the network and each node is capability to transmit data directly to the base station or sink node. It also assumes that each node the network has equal energy and they will die at the same time. Since all the nodes in the network are static the chain is constructed using greedy approach. The node far away from the sink or base station will initiate the chain formation. Each node in a chain receives data from its previous neighbour and sends the gathered data to its next neighbour in the chain [34]. To find closest neighbour each node uses signal strength and alters the signal strength to that they will hear only one reply. From both sides node passes token through the chain to head. At the time of building the chain each node fuses the received information with own information. In every round, chain can transmit the aggregated information to the BS by a randomly chosen node i.e. leader node. The chain composed of those nodes that are closest to each other and form a path to the sink or BS. The aggregated data is sent to the base station by the leader node of the chain.

PEGASIS protocol surpasses LEACH by eliminating the overhead caused by dynamic cluster formation, minimizes the distance between the nodes and limits the variety of transmission. All the nodes require global information regardingthe network. This is a disadvantage of this protocol because at any time it will be collected from the network [35].

Reducing energy consumption in this technique is accomplished by following ways:

- Only one node in the network is transmitting data to the base station during a given round. Since the transmission range to the base station is large, with regards to energy savings this will result in an improvement.
- The energy consumed by each node is also reduced because all the nodes communicate with their nearest neighbour.
- All nodes perform data-fusion, effectively distributing the energy needed for this task across the network.
- The overhead related with dynamic cluster formation during every round is eliminated.

Simulation in C has shown that PEGASIS protocol results in 100% to 300% improvement over LEACH for a number of different network sizes and configurations [36].

• **AODV:** Ad hoc on-demand distance vector (AODV) routing protocol is a reactive routing protocol. Advantages of both DSR and DSDV routing protocols are combined in it. The on demand route discovery process and route maintenance from DSR routing protocol and hop-by-hop routing, node sequence number utilization from DSDV routing protocol are included in AODV routing protocol. Each node maintains a routing table which has information regarding its neighbour nodes [37]. In AODV the routes are created whenever needed means the routes are created when source node need it. The source node transmits a route request packet (RREQ) to all its neighbouring nodes having the destination node's sequence number in it. After receiving the RREQ the nodes check for valid path to the destination if path is available then they send a Route Reply packet (RREP) to the destination which travels the opposite path in the network. After receiving the RREP from its neighbours source node starts transmitting the data [38].

• **AOMDV:** The extension of AODV protocol is Ad hoc on-demand Multi-path Distance Vector (AOMDV) routing protocol it is also a reactive protocol it is used for determining multiple loop free and link disjoint paths. It allows intermediate nodes to reply the requests when AOMDV select the disjoint path. Along with the respective hop counts AOMDV has a list of the next-hops routing

entries for each destination. To all next hops same sequence no. is allotted which helps in keeping a path of route. A node keeps record of the allotted hop count, which is the maximum hop count for all the paths at each node. As DSDV provides multiple paths to the destination the loop freedom is guaranteed by a node taking another path if it has a less number of hop counts to the destination [39]. Its message overhead is at the time of route discovery due to increased flooding. Since it is a multi-path routing protocol, the destination node replies to the multiple requests those results are in longer overhead [40].

5. Conclusion

In this paper we have discussed number of clustering techniques, specifically with respect to their energy consumption and reliability needs. In wireless sensor network the limited energy of sensor nodes plays a vital role in designing any protocol. In addition, delay, data loss tolerance, and lifetime of the network expose reliability issues when designing recovery scheme for clustering techniques. These important characteristics are usually opposed, as one often has a negative impact on the other.

Protocols and techniques given in this paper provide a promising improvement over standard techniques of clustering but there are still lots of work to be done.

Several energy enhancements up to now have targeted with reduction of energy associated within the cluster head choice method or with generating a desirable distribution of cluster heads. Optimal clustering in terms of energy efficiency ought to eliminate all overhead associated not solely with the cluster head choice process, however additionally with node association to their several cluster heads. Sensor network reliability is presently addressed in numerous algorithms by utilizing re-clustering that happens at numerous time intervals; but the result's usually energy inefficient and limits the time available inside a network for data transmission and sensing tasks. Additional enhancements in reliability ought to examine possible modifications to the re-clustering mechanisms following the initial cluster head choice. These modifications ought to be able to adapt the network clusters to take care of network connectivity whereas reducing the wasteful resources related to periodic re-clustering. In addition, alternative mechanisms like the power of nodes to maintain membership in auxiliary clusters will reinforce the current state of sensor network reliability.

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