Study of Hotspot mitigating techniques in Wireless Sensor Networks

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Abstract: Wireless sensor networks (WSNs) are combination of sensor nodes having communication abilities. These nodes consist battery for power consumption which is limited, sensors and processors for computing abilities. The major challenge of WSN is to improve the network lifetime. As the power is limited various energy efficient protocols are designed to achieve the goal to utilize minimum energy. Hotspot Problem is one of the problems that have major impact on network lifetime. The Hotspot Problem is a situation or circumstance when the nodes near sink consumes more energy and become dead faster than those are far from sink. This creates energy imbalance in the network and sufficient energy remains unused. Various routing techniques are designed to remove or to avoid hotspot problem. This paper discusses different routing techniques that solves hotspot problem and also discusses the effect of these techniques. A survey is done on these different techniques that are used to remove Hotspot Problem.

Index Terms - Wireless sensor networks, Hot-Spot problem, Multi hop routing, Routing techniques

1. INTRODUCTION

Wireless sensor network is the collection of various sensor nodes and each sensor node has computational abilities and battery. These nodes are connected to each other by a wireless communication via RF or lasers. These sensor nodes cover the area that required to be monitored. The sensors in the nodes sense the physical environment and process it and send it to the base station. The base stations act as a gateway between sensor nodes and the end user. The data send by the sensor node to base station via single or multiple hops. The nodes can be stationary or moving that depends on application. The sensor nodes consist processing unit with limited computational ability, sensors for environment monitoring and wireless trans receiver to send data packets. The main purpose is to develop multifunctional, low power and low-cost system that can be utilized in real world applications [1].
The recent advancements in the growing technological world has grabbed the revolution in the sensing technology as well [2]. It has made it possible to generate different sensors that can perform different operations dedicated to numerous applications. The deployment of these sensors is done based on the different topological deployment scenarios. Most of the times, these sensors are deployed randomly to avoid any kind of complexity in the deployment of the sensor nodes [3]. The profile of these sensor nodes varies from the temperature sensor to vibration, moisture and various others form depending upon the applications for which they are being used. Over the years, it has been observed that the sensor nodes have found them irreplaceable options for the harsh environment monitoring due to their self-configured nature. The sensor nodes work on the simple operation that they sense the surroundings and the collected data is being forward to the base station or the sink where the data is processed for the further required operations that may include the information to the rescue team [4].

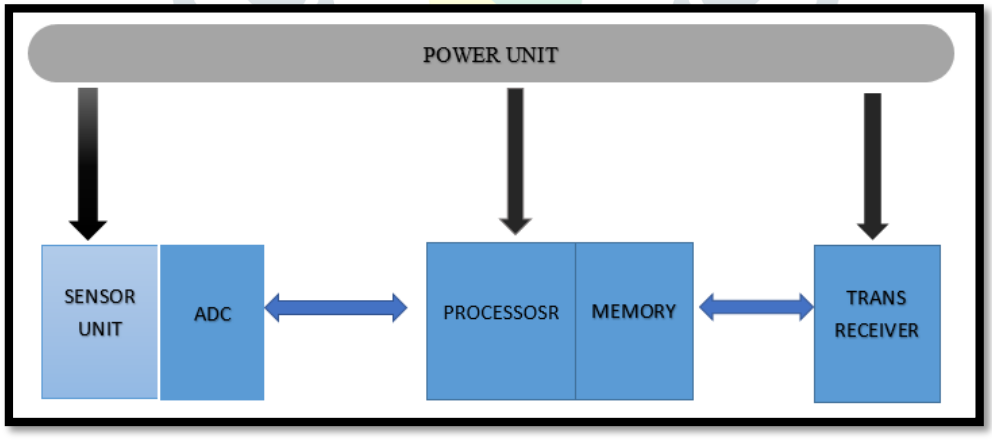

Fig. 1. WSN architecture

Fig1 shows the node architecture consisting battery power which is limited. Sensor unit consists various sensors required according to the application. Processing Unit consist microcontroller that process the data and trans receiver to transmit and receive data packets. Every unit consumes power to operate and battery as source of power is limited, it is required to utilize minimum as possible. Various Energy efficient protocols are designed to increase the network lifetime. Routing protocols are designed so that data packets send from source to destination with consuming minimum power.
WSN is utilized in various applications like in military, agriculture, industrial and commercial. In military, it is used for intruder detection or monitoring of soldiers, battlefield surveillance, nuclear, biological and chemical attack detection, monitoring and surveillance of borders. Forest fire detection where nodes in the forest are equipped with sensors to measure gases and temperature that are produced during fire, if node detects it, then it sends alarm message. WSNs also used for air pollution and Water quality monitoring. Land slide detection also possible using wireless sensor nodes [5]. In Medical Field the use of WSN is tracking and monitoring patients and doctors inside the hospital. And Drug administration. Industrial applications provide conservation, efficiency, control and safety by reducing the cost of energy by optimized manufacturing processes, identify an inefficient operation

or some poorly performing equipment. To reduce the user intervention, it helps to automate the data acquisition from remote sensors. To improve the preventive maintenance programs, it provides the detailed data [6].

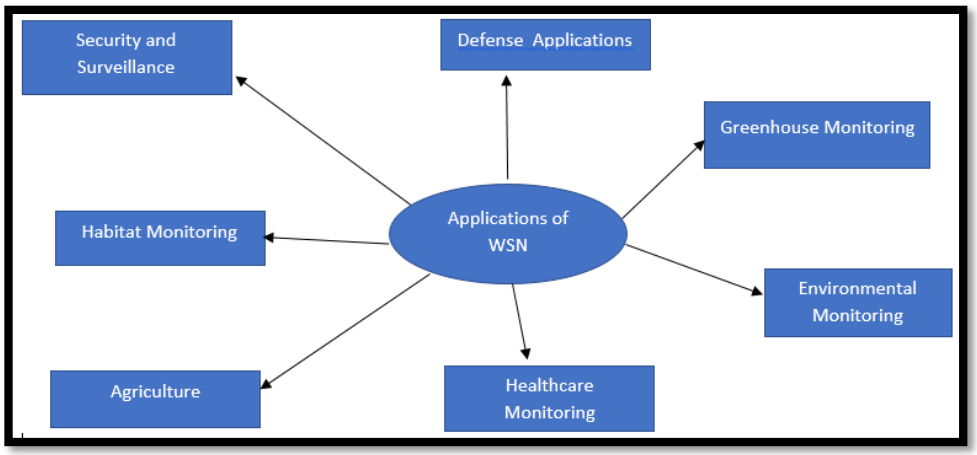

Fig. 2 Applications of WSN

Most common problem of multi hop WSN is the relay of data among the CH nodes. While relaying the data, the CH nodes consumes a lot of energy and eventually dies. This problem is termed as hot-spot as hot-spot is created at the place where node is dead [7]. Consequently, the no-connection zone is created between the nodes and sink. There have been various methods that have tried to overcome this problem; however, the selection of CH can be improved to the better level which could help in avoiding this hot-spot problem at high magnitude [8].

2. Literature review

The focus of the literature study has been on the multi hop routing techniques. While forwarding data packets to the other nodes lying on the way to the sink, the nodes placed nearer face hot-spot problem. The various techniques have been discussed which have focused on mitigating the same, these techniques are discussed as below.

Li & Mohapatra[9] present an analytical model to analyze the energy hole problem assuming all nodes are uniformly distributed in a circular network. This model examines the all possible methods that are aimed to remove or avoid the energy hole problem. It is observed that hierarchical deployment of nodes and data compression in uniformly distributed network has a positive effect whereas adding more nodes makes little difference in the network lifetime.

Yu et al.[10] presents hole geometric modelling to solve hole problem by geographic forwarding mechanism i.e each nodes can get location information of itself and all its 1 hop neighbors in sensor network .This mechanism reduce route rediscovery overhead as it prevents data packets from entering the stuck area of the hole It also reduces energy consumption and data collisions of nodes at the boundary of holes.

Wu et al. [11] presents routing with non-uniform node distribution assuming nodes are deployed in circular area and sink is located at the center of the area that addresses the energy hole problem in WSNs. The whole network is divided into coronas and more nodes are assigned to the inner corona. It is obsereved that the network achieves high energy efficiency using non uniform node distribution and 15 percent less energy is wasted. It also has advantage in network lifetime and data delivery ratio. The disadvantage of this strategy is cost of sensor nodes and requirement of a perfect MAC layer that handles channel problem among the nodes.

Li et al [21]introduced a novel energy-efficient clustering mechanism for WSNs. The hot spots problem appears when employing the multi hop routing in a clustering approach. It is being argued that both the rotation of cluster heads and the metric of residual energy are not sufficient to balance the energy consumption across the network. To address the problem, an unequal clustering mechanism to balance the energy consumption among cluster heads was introduced.

Gong et al. [22] has proposed a multi hop routing protocol with unequal clustering (MRPUC) to acquire the objective of enhanced network lifetime in WSN. The relay nodes are used to forward the data to the base station by the CHs who have collected data from their respective clusters. Moreover, there are many measures that are considered by the MRPUC algorithm. These measures include the selection of nodes as CH which have higher energy and in addition to it, it also makes the clusters smaller in size which are placed nearer to the sink as compared to ones which are far located.

Yang and Zhang [23] presented a novel energy balancing unequal clustering protocol (EB-UCP) for wireless sensor network. EB-UCP achieved a better performance in terms of lifetime by using the concept of unequal clustering and balancing the energy consumption in the network. A unequal clustering algorithm is employed to form clusters. The size of cluster is made varied according to the distance of cluster from the Base Station. The cluster nearer to the Base Station are smaller in size to preserve the energy so as to forward the data to Base Station. Moreover, the distribution of sensor nodes is deployed according to the energy balancing algorithm and therefore the energy consumption in every layer is nearly equal. Simulation have shown that EB-UCP outperforms EEUC and LEACH protocols.

Nurhayati [24] has proposed an Energy Efficient based on Mechanism Unequal Clustering Routing Protocol Wireless Sensor Networks. This enabled the energy dissipation among the Cluster Head nodes, thus increasing network lifetime. In this routing hierarchical structure and multi-hop, before clustering is processed. The different of this routing algorithm are the nodes with the highest energy Chooses as Cluster Head Leader Node.

Jun Yue [25]addressed the problem in cluster-based and homogeneous WSNs in which CH performs the transmission of data in single hop communication. The algorithm it proposed is named as energy efficient and balanced cluster-based data aggregation algorithm (EEBCDA). The proposed algorithm divides the network into rectangular grids with unequal size and makes cluster heads rotate among the nodes in each grid respectively, the grid whose cluster head consumes more energy has more sensor nodes to take part in cluster head rotation and share energy load, by this way, it is able to balance energy dissipation.

U. Hari et al. in [26] proposed unequal clustering routing protocol mechanism. The UCMR protocol has different cluster size based on its distance with reference to base station. In this unequal clustering protocol the selection of cluster head is based on remaining energy, node degree and distance from the centroid.. The multi-hop transmission in this protocol can improve QoS parameters like error rate and data rate. Simulation results shows that UCMR extends the network lifetime by 40% and 75% over UCR and LEACH protocols respectively.

Rani et al. in [27] proposed Chain Based Cluster Cooperative Protocol (CBCCP). CBCCP collect information from inaccessible areas by using factorization of the area into subareas (clusters) and appointing cluster head in each of the subarea. Routing is based on the predefined path. Transmission distance is minimized by using cluster coordinators for inter cluster communication and CH within the cluster. Chain Based Cluster Cooperative Protocol (CBCCP) performs very well in terms of energy and time. CBCCP protocol consumes six times less energy than LEACH, five times less energy than SEP, four time less energy than genetic HCR.

R. Mohemed et al. in [28] proposed two distributed, energy-efficient, and connectivity-aware routing protocols for solving the routing hole problem. These protocols are On-Hole Children Reconnection (OHCR) with local nature and On-Hole Alert (OHA) with global nature. Both OHCR and OHA add no network overhead during network stability since both work on node loss case.

Alnawafa and Marghescu in [29] proposed an approach in which whole network is divided into numerous levels. It is the position and the status that decides how the sensor node has to act. Two routing strategies; static and dynamic have been proposed that decides for the route between the nodes. It is observed through the simulations that the proposed technique outperform the other techniques in terms of network lifetime, throughput and various other metrics. However, this algorithm could not save itself from the hot-spot problem.

2.1 Inferences drawn from the literature survey

Since the development of WSN, it is observed from the literature review, that the battery constraints on the WSN has introduced various limitations in its exploration to the various applications. The energy efficient routing has made it possible to elongate the battery survival for acquiring enhanced network performance.

a) The large area networks seek multi hop communication it is because the sensor nodes are located at the very far distance from the sink. Therefore, if the nodes will follow single hop, the nodes will consume a large amount of energy.
b) It is studied from the literature that many techniques have suffered from hot spot problem which is due to the burdening of nodes in the multi hop communication.
c) Many techniques have been proposed in the literature, that tend to remove hot spot problem. However, it is observed that these techniques tend to avoid hot spot with the used of some corona-based models.
d) These models still face various challenges and the host spot problem still exists.
e) It is further observed that the CH selection can be further improved in such techniques which are focusing on the removal of hot spot problem.

3. Conclusion

This paper provides a survey of the work that focus on the improvement in network lifetime and performance of WSN through efficient routing techniques that remove the hotspot problem. Hotspot problem can arise in both cases when base station is inside or outside the network. EH problem is more dominant when base station is outside the network as base station is outside the network, the distance between sink and base station is large and more energy is required to transmit the data. So Hotspot problem are discussed in long haul transmissions. This paper provide broad coverage of the work and it discusses different routing techniques along with the key challenges and future scope in the area.

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