ABSTRACT

Wireless sensor network (WSN) consists of a large number of small battery-powered wireless sensor nodes that are scattered over an area of interest. These sensor nodes collect the relevant data from the environment, and then send the gathered data to a central processing base station called sink. In a typical WSN scenario, all the data are routed back to the static sink. Therefore, those sensor nodes near the sink have to forward all the data from sensor nodes that are away from the sink and thus carry a heavier traffic load. Consequently, the sensor nodes near the sink drain their energy quickly and are more susceptible to energy exhaustion. When these sensor nodes use up all their energy (called energy hole), no more data can be transmitted back to the sink, causing dysfunctional or disconnected network or premature lifetime of WSN. This is called energy hole problem which is a critical issue for data gathering in WSN. The main objective of this dissertation is to alleviate the formation of energy hole near the static sink by reducing the burden on the nodes near the sink. Various strategies or techniques have been proposed in this thesis to reduce the energy hole problem. The dissertation consists of three works and an extension of one of the works.

The first work presents K-level based Transmission range scheme to ease the formation of energy hole near the static sink by distributing the energy consumption uniformly across the network. A combination of controlled region selection strategy along with maximum residual energy
node selection is employed. A sensor node determines its list of possible next hop nodes using a controlled region selection strategy based on value of K where K indicates the number of corona level jump. From the list of possible next hop nodes, a node whose residual energy is maximum is chosen as its next hop node. Using K-level based transmission range scheme, a new set of next hop nodes are selected every time a different K value is chosen during the renewal phase. This scheme avoids repeated and random selection of a node which occurs in normal fixed transmission range scheme. Using the controlled region selection along with maximum residual energy node selection, the burden of forwarding the data to sink shifts from nodes near the sink to higher level of coronas. This ensures that energy dissipation takes place equally in higher level of coronas as well. K-level based transmission range scheme performs better than normal fixed transmission range scheme in terms of end-to-end delay, network lifetime and energy dissipation. Theoretical performance analysis using circular corona model is also presented in terms of load per node, total hop count and average delay. The drawback or limitation of this approach is that for higher number of nodes per corona packet delivery ratio becomes lesser or in other words congestion becomes higher at the static sink.

Second work presents another strategy to overcome energy hole problem. Beacon based data collection scheme using mobile sink is employed in order to distribute the energy consumption uniformly across the network. Two types of sink mobility are explored to find an optimum path for improving the network performance. One is random mobility and the other is predefined path mobility. In predefined path mobility various types are
explored namely mid-square, diagonal cross, mid-cross square and mid-cross path. Network performance is evaluated using Beacon Based Data Collection (BBDC) scheme for predefined and random path mobility for the mobile sink. It is compared with static sink data collection. Finding the optimum path for mobile sink, impact of increasing the pause points and the effect of increasing the number of mobile sinks on BBDC scheme to improve network lifetime is analyzed. It is seen that among the predefined paths, mid-square path has minimum end-to-end delay and diagonal cross has maximum end-to-end delay. The end-to-end delay is least in case of static sink which is due to absence of travel time, pause time and number of pause points. Further, it is observed that predefined mid-square path performs better compared to other predefined paths in terms of network lifetime, energy dissipation and end-to-end delay. It could be concluded that optimum path for mobile sink is predefined mid-square path. This approach not only removes the burden on nodes closer to sink but also reduce the congestion near the sink. But the limitation in using the mobile sink approach is that end-to-end delay is higher compared to the static sink approach.

The third work presents a very innovative approach using clustering technique to alleviate the energy hole problem. Grid based clustering (GBC) using static sink along with dual cluster heads (a combination of primary and secondary cluster head) is used to achieve enhanced energy balance in the network, thereby extending the network lifetime. The system design consists of the following tasks namely centralized cluster configuration, secondary cluster head selection, determining neighboring cluster heads, data collection phase and renewal phase. The static sink is responsible for initial cluster
configuration by centralized algorithm. It involves grid formation, finding the mid-point of each grid cell, identification of nodes in each grid cell by node-Id and grid-Id, cluster head selection and finally broadcast of grid cell information in the network by the sink. The important contribution of the work is the ease of grid cell formation and selection of cluster heads by centralized cluster configuration. Secondly, GBC addresses the constraints in clustering schemes like choosing the cluster heads at the start up of the operation and ensures equal sized clusters for better energy balance in the network. Analysis and simulation results show that GBC using the static sink (GBC-SS) performs significantly better than LEACH (Low Energy Adaptive Clustering Hierarchy) and UCR (Unequal Cluster-based Routing) in terms of network lifetime and energy dissipation. Theoretical analysis of the Grid based clustering is also presented.

An extension of the third work namely GBC scheme using mobile sink (GBC-MS) and hybrid sink (GBC-HS) for data collection to alleviate energy hole problem is proposed. The simulation results show that the GBC-MS performs better than GBC-SS as well as other clustering schemes in terms of network lifetime and energy dissipation. But one limitation using the GBC-MS is that end-to-end delay is very much higher compared to GBC-SS which is a limitation in case of delay sensitive applications. With additional improvement GBC-HS (using hybrid sink - a combination of static and mobile sink) overcomes this limitation along with better energy balance in the network. GBC-HS also out performs GBC-SS and GBC-MS in terms of network lifetime, energy dissipation and end-to-end delay.