Chapter 7

Conclusions and Future Work

7.1 Thesis Summary

This thesis has considered the new methods for the aggregation of data in the agricultural field. This has led to the development of automated information collection system which in turn provides a decision support system to the farmers.

A general overview of the wireless sensor network, its architecture was discussed in Chapter 1. Sensor nodes have a lot of resource constraints; main among them is the memory, energy and computational power.

Chapter 2 has been devoted to the survey of related work on various topics associated with the proposed work. The current work is based on the on-going CSN project. The application where the current work is of relevance is studied. Usage of sensors in the agricultural application and the study of already existing project are considered. Energy Computation is carried out in different ways by the classical and μAMPS model. The current work uses the μAMPS model. The criteria for maintaining the connectivity between the sensors and covering the area of importance are deliberated upon. The k order connectivity helps in deciding the number of neighbours that is required in the vicinity of any node. In order to substantiate the work, various ways of deploying the sensors like the triangular, hexagonal, square type are considered. Various classifications of routing techniques, methods and processes are studied. Survey on clustering and aggregation algorithm reflects that it changes with each application.

Various simulators are studied. Due to the popularity of ns2, being a freeware and lot of patches available online, with lot of researchers using this
simulator, ns2 is chosen for the current work. After having an insight into various work carried out so far some of the features are incorporated in the current work.

The entire suggested algorithms in the literature infer that data is aggregated, without actually working on the data.

The current application uses Tinynode. In Chapter 3 using the data from the fact sheet, the application scenario is designed as close as possible to the real world. The height, distance of transmission, the power and energy consumption is computed for the sensor node. Energy consumed during the path establishment, discovery and data transmission are calculated. The minimum energy of 1.8 J is required for transmission to take place without dropping a packet. Various topologies are studied and the best way to deploy sensors taking into account the transmission range is gratified. Of the square, triangular and hexagonal topologies, the maximum amount of energy consumed are in the case of triangular topology followed by square and hexagonal. Square and hexagonal offer almost the same energy consumption. An application where reliable network is required triangular topology is the best option among the three categories.

Data transmission and reception consume considerable amount of energy. Finding an appropriate path with minimum hops will reduce the transmission and reception count and in turn the consumption of energy. Good amount of energy is consumed to find a new path. If the chosen path is the one which runs for long interval of time, repeated path discovery can be avoided saving sufficient energy. Various routing algorithms are studied. The current project is based on the CSN project which uses AODV protocol. In Chapter 4 the AODV protocol is changed to adapt to the current application and a new protocol B-AODV is formulated. Path maintenance is carried out using TRACK_BACK algorithm so that dropping of packets can be avoided. New protocols based on the B-AODV are designed. Uniform energy consumption protocol changes the path of data delivery when the current node loses its energy to half its initial value. This avoids the ‘hot spot’ formation with certain nodes draining their energy completely. S-AODV finds path such that the broadcasting of control packets are avoided beyond the minimum hops required.
This protocol assumes the node under consideration is aware of its positional information along with that of the base station. T-AODV chooses a path with higher amount of total residual energy along the path. M-AODV finds a path with maximum amount of minimum energy among nodes along the path. Comparison of various routing techniques is studied. SMTU-AODV is used in the successive chapter to finding a path between coordinating nodes. This protocol has all the advantages of the above mentioned protocol.

Ns-2 does not support data handling. The application layer along with UDP layer is extended to incorporate the handling of data. This data is also processed at the network layer. In Chapter 5, aggregation of data is carried out. Two types of aggregation are carried out. The position of the coordinating node is as per the hexagonal and square topology of Chapter 3. The route between the coordinating nodes is followed as per the procedure in Chapter 4. Data from all the nodes are updated in the routing table. The non-coordinating nodes send their data information to their coordinating nodes. In the case of finding the min | max value in the whole network, all the data from the non-coordinating node and from the current coordinating node or the data from previous hop coordinating node are compared with each other. The minimum among this value is transmitted to the next hop neighbour. The process repeated until it reaches the base station. This process creates a tree structure providing early aggregation more close to the source node. The other type of aggregation is to find the average reading at a particular location in the field. The non-coordinating node aggregates the value with the coordinator node, at the specified coordinating node around which the aggregate value is to be obtained. The other nodes along the path just act as routers without contributing their data. Events are also triggered when the data is above or below the required moisture content in the field. The battery low information is also sent to the operator at the base station. This gives the system administrator information to divert the water flow. This also provides an instruction to the operator to change the batteries used by sensors which have low power, in case the data at the current sensor location is crucial.
The procedure in Chapter 5 only gives an average or minimum value. If the data of all the nodes in the network bearing a little higher accuracy is desired, then in Chapter 6 a new protocol is devised based on correlated value. The whole region of interest is classified into clusters such that each cluster region is in the hearing range of its four neighbouring clusters. A node which is approximately at the centre of the cluster forms the cluster head. A path is established between the nodes within the clusters such that, a node which is farther away from the centre will associate with a node closer to the centre of the cluster head. If the neighbouring node is farther than its distance with its cluster head, the association is done towards the cluster head. A route is also established between the cluster head using the procedure of Chapter 4. Each node has a count of how many hop counts is needed to reach the cluster head. Based on this, the data is sent from far away node within the cluster towards the cluster head. It follows a path such that the data along the path are likely to be related. If the values along the way are related the counter corresponding to the related data is incremented. The unrelated data is appended to the packet header. The counter helps in aggregating the value of related data within the cluster at the cluster head. This aggregated data is forwarded to the next hop neighbour where the aggregated information is appended to the common packet header.

With aggregation the added overhead is latency. The child nodes of the aggregation tree can send their data immediately. The nodes higher up in the tree will have to wait for its child nodes to send the data. This causes delay in the output. If there is no proper time synchronization between these branches there could be a possibility of loss of important information as in the case of min|max information of the whole network. If it is a data arriving out of synchronization, data is obtained at the base station with delay. This adds additional overhead due to reprocessing of information at the base station.
7.2 Contributions of the Thesis

The major contributions of this dissertation can be summarized as:

- Setting up physical environment close to that of the agricultural application with appropriate deployment to implement the same.
- Designing various routing techniques so that it is better than the currently used AODV protocol.
- Aggregating the data in the network so that the computation and communication at the base station are reduced conserving energy.
- Correlated data aggregation and data assimilation techniques are used so as to send related data together using dynamic sized data packet.

The entire work is implemented on ns2 for simulation, and results show the improvements.

This proposed work has resulted in an automated decision system which is beneficial to farmers with huge field area.

7.3 Future Directions

There are several possible directions, in which to extend the research presented in the current work.

Balancing Consumption of Energy

Balancing the energy consumption can provide fairness in the lifetime of sensor nodes. By avoiding the so-called “hot spots” (heavily loaded sensor nodes that die earlier than other nodes due to depleted energy) in the network, we can avoid draining of energy of selected few nodes. Balancing the energy consumption may not lead to a minimal overall energy consumption but assists in having a longer life for the network. Future work is needed to justify the tradeoffs between balancing the energy cost and minimizing the overall energy costs.
Latency Constraint

Nodes may delay data in order to aggregate them into a single packet before forwarding them towards some central node (sink). However, many applications impose constraints on data freshness; this translates into latency constraints for data arriving at the sink. Latency constraint is not considered due to its high complexity.

Sleep Scheduling

Sleep scheduling minimizes the total energy cost of waking sensor nodes, while still achieving a certain degree of energy balance across the system. Sleep Scheduling is also an important and widely used technology for low-traffic scenarios.

Mobility in the Sink

An interesting approach for information processing and routing in mobile WSN is to use mobile nodes to transport and gather information from stationary nodes. A large portion of the system energy is spent moving the mobile nodes. Carefully scheduled node movements are crucial to maximize the system lifetime. Information availability and correlation among sources can be used to schedule the movements, so that energy is saved by avoiding collection of nodes with unchanged information.

Synchronization

Packets which arrive out of sequence need to be handled appropriately. This avoids unwanted delays, additional routing load and in turn consumption of energy.

Security

Security is an important concern because of the openness of the field where sensors are deployed. Physical attack and tampering or altering the acquired information in the network can create wrong interpretation of acquired information.
These avenues of research are chosen to address issues including node mobility, wireless communication reliability and integration with existing technologies.

From the perspective of the entire system, the topology and routing control at the routing layer leads to a possible re-construction of the network infrastructure, including clustering and routing.