CHAPTER 7

CONCLUSION & FUTURE WORK

The Layer Based Time Constrained Reliable Data Acquisition Mechanism (LTCRDM) has been proposed with the objective of improving the reliability of process of acquiring data gathered by the deployed sensor nodes with high packet delivery ratio and low network latency. The results obtained from simulations and experiments indicate that the mechanism achieves the objectives satisfactorily.

The results indicate that the mechanism Distance Based Multi-Layer Assignment Mechanism (DBMLAM), successfully categorizes deployed nodes into layers, both for the Centralized & Distributed Decision Making approach (Single Sink & Multiple Actuator/Sink). The non-uniform size and shape of the layers leads to the conclusion that RSSI does get affected by multiple channel characteristics which change over time, as well as the random deployment of the nodes thus leading to non-uniform distribution of nodes into layers. This could affect the number of neighbours available for ensuring reliability.

The observations further indicate that the Layer Based Neighbours (LBN) mechanism also works satisfactorily with successful identification of deployed nodes as Downstream, Upstream, adjacent & Layer Bypass neighbours. Initially, however, it was also observed that some nodes could not be identified as neighbours and were left as orphans, as is predicted by Hamida et al [32]. The mechanism was strengthened by including multiple exchanges of packets to ensure that all nods were identified as neighbours.

The results obtained during simulations and experiments indicate that the concept of layers, layer based neighbours, neighbour success rate (Ant Colony based) and usage of explicit and implicit acknowledgements, which form the heart of Layer Based Time Constrained Reliable Data Acquisition Mechanism (LTCRDMA), have a direct positive impact on the successful delivery of packets at the sink within the network latency time constraint $T_{NLT}$. 
This leads to the conclusion that usage of the above techniques does in fact reduce the number of hops and the number of re-transmissions required to deliver a packet successfully to the sink within the constraint of the network latency time $T_{\text{NLT}}$. However, the results also indicate that the effectiveness of the mechanism may be less if the number of hops increases.

It is clear that network latency will involve some energy trade-off\cite{92} as the benefit achieved in terms of reduction is Network Latency is because of higher energy cost of communication which goes up because of reduction in number of hops. However this offset to an extent by the comparatively lesser number of re-transmissions required.

LTCRDM-C&D along with LQDM-C & D present a composite set of algorithms for reliable collection of information as well as for reliable dissemination of a query in a WSN. In conclusion it is safe to state that the potential of utilization of these, in view of the overall shift towards WSAN applications in various fields, is very high. The limitations of the current work along with the improvements required to be made as part of future work are discussed next.

**Limitations of Current Work & Future Work**

The limitations of the current work are as below:

1. LTCRDM uses the method of establishing layers to setup a gradient between the nodes and the sink in Centralized Decision making approach and between the actuators and the nodes in the Distributed decision making approach. However, LTCRDM, in its current form does not have the ability to transfer information between specifically chosen destination node besides the sink or actuators.

2. The Layer based Query dissemination Mechanism (LQDM), in Centralized Decision making scenario, takes longer to disseminate the query if the number of nodes is quite large.

3. The distribution of the layers is not optimized for energy efficiency. This is primarily because the distance between the nodes and the sink is not known as the nodes are randomly distributed.
4. There is no mechanism available by which a node can intimate the sink/actuators that it is unable to find a neighbor.
5. Significant energy efficiency can be achieved if nodes can be put to sleep when they are not performing any specific function. LTCRDM does not propose any mechanism towards this.
6. LTCRDM does not contain a mechanism which can stop re-transmission of a packet towards sink if it has already crossed the $T_{\text{NL}}T_{\text{max}}$ limit.
7. LTCRDM does not offer any support for mobile nodes and sinks.
8. Despite usage of explicit and implicit acknowledgement duplicate packet re-transmission still occurs on loss of the acknowledgement.

Future work could address the limitations mentioned above with special focus on cross-layer design for improving the energy efficiency of the network. More focus could be put on the control action itself and the communication between the actuators themselves. The data acquisition process can also be studied from the perspective of other QoS parameters like jitter, throughput etc. and the effect of maintaining these parameters on the Reliability of Data Acquisition can be studied. Moreover the mobility of the nodes and its impact on the Reliability of Data Acquisition can also be an interesting issue for future work. Future work can also be done in the direction of improving the Energy consumption of the nodes by adding scheduling algorithms.