# Chapter 6
# Conclusion and Future Work

A routing algorithm that considers the variability of the wireless link quality is obliged to be acquainted with a few aspects of the ad-hoc networks, like the stationary topologies and shared wireless medium, since the hop count metric is not familiar with the way of the wireless link. The shortest path metric is concerned with uncovering a way between source-destination match paying little mind to how proficient the way is. As it is not aware of the nature of the wireless link, a link of low quality could be chosen resulting in degradation in the performance of the network. A cross-layer technique should be employed for routing to consider factors such as interference, bandwidth availability, etc., from various layers allowing information exchanged between protocol layers, to help in finding reliable and efficient paths to enhance the performance of the network.

The wireless medium is shared among the mobile nodes in ad-hoc networks so the link does not have a dedicated bandwidth. So, an efficient routing protocol must consider the contention parameter for accessing the medium before competing for the flow. The nodes in the network contend for access to the wireless medium using the IEEE 802.11 DCF MAC mechanism, a high level of contention for access to the medium will result in a low availability of bandwidth at a node. The DSR algorithm is modified by adding Access Efficiency Factor (AEF) as the cost metric for the routing mechanism. It reflects the contention level of nodes experienced locally, it is used as an alternative to hop count. In this modification, the selected path is identified by finding a path with the highest minimum AEF value. The modified DSR routing mechanism is based upon avoiding congested nodes where packet loss is likely to occur. The objective of this work is to utilize locally generated MAC layer information at the routing layer to improve the global performance of the network.

The problems related to power efficient routing through cross-layer architecture is of prime importance in mobile ad-hoc networks. A proper cross-layer interaction with the benefits of power efficient routing is rare. The existing systems are with one or more types of delimitation in power efficient routing. In this thesis, cross-layer interaction among physical layer, MAC layer, and routing layers with the objective of power efficient routing has been addressed. This chapter summarizes the discussion and outlines the main conclusions.

The minimum energy consumed by the packet *j* to traverse from a source node $n_1$ to destination node $n_k$ from hop *a* to *b* by assuming *T(a, b)* as the energy consumed in transmitting or receiving one packet over hop *a* to *b*, can be given as

$$e_j = \sum_{i=1}^{k-1} T(n_i, n_{i+1}) \tag{6.1}$$

where the goal is to minimize $e_j$ for all packets *j*. Under light loads, the routes are selected when this metric becomes identical to routes selected by shortest-hop routing. If it is assumed that $T(a, b) = T$ where *T* is a constant for all $(a, b)$ belonging to *E* which is a set of edges, then the power consumed is $(k - 1)T$. To minimize this value it is needed to minimize *k* that is like finding the shortest-hop route. Thus, if one or more nodes on the shortest-hop path are heavily loaded, the amount of energy expended in transmitting one packet over one hop will not be a constant since variable amounts of energy (per hop) is expended on contention. Thus, this metric will tend to route packets around congested areas and possibly increasing hop-count. A problem with this metric is that nodes will tend to have widely differencing energy consumption profiles that result in early death of nodes.

Reduction in power consumption in ad-hoc networks are of great importance since the nodes operate with limited battery power. Two important aspects in MANETs are total transmission power and prolonging the lifetime of nodes. In order to maximize the lifetime of these networks, network related transactions through each mobile node must be controlled such that the power dissipation rates of all nodes are nearly same.

The important aspects that are outlined in this thesis are follows:

1. This thesis provides a study of the wireless ad-hoc networks. The different cross-layer architecture is discussed along with the overview classifications of the conserving energy routing protocols. Different groups of energy conservation protocols are analyzed based

on switching on/off transmitters to save energy, routing based on energy consumption metrics, network topology controlled by adjusting transmitter radio. Cross-layer interaction with energy efficient routing metric has been focused in this thesis.

2. In chapter 3, the major sources of energy consumption due to packet transmission, packet reception, idle waiting, and sleep modes are considered. The energy expended while dispatching a data packet has been mathematically modeled. DSR algorithm has been modified to incorporate the energy metric in route discovery process and route maintenance process. In the route discovery process, the source node issues RREQ packet that is flooded to neighbour nodes. The node only responds to the RREQ packet with enough energy supply and forwards it. The destination node selects the route according to the cost of each path.

3. The route maintenance phase is modified by considering the node mobility aspects. To minimize control traffic, local maintenance approach has been adopted. Whenever the change of cost of any node along the path becomes greater than a fixed threshold value, the route is deleted.

4. In Chapter 4, the cross-layer interaction of the MAC layer with the network layer has been proposed. The different nature of nodes like different transmission power, bandwidth, battery life, and transmission rate leads to hidden/exposed terminal problems. The routing protocols perform poorly due to asymmetric links. The MAC layer IEEE 802.11 protocol has been modified to tackle the problem. The routing layer does the routing based on the information from the MAC layer. Extensive simulations have been carried out in NS 2.34 simulator, to compare performance based on channel quality, mobility, congestion in between DSR, AODV and Cross-Layer Design (CLD) protocol.

5. The three-layer interaction of physical layer, MAC layer, and network layer has been analyzed and discussed in Chapter 5. In order to get rid of energy wastage, it is always better to be well prepared about the congestion status. Through cross-layer design, energy can be conserved if congestion can be controlled. It involves two schemes: rate adaptation and congestion aware. Through rate adaptation the data rates in MAC layer can be adapted based on channel estimation from physical layer and congestion information from the

network layer. The congestion aware can be exploited from the congestion information in the network layer from MAC layer. The aim of the simulation done in this chapter is to show the effect of rate adaptation and use of the routing metrics. Two scenarios are considered for the experiment: stationary and pedestrian. The modified DSR algorithm that considers interference awareness with rate adaptation performs better in high node mobility and dynamic topology.

**Future Works**

1. Full mobility, extreme environment conditions, high variability of the channel, high loads of the nodes, etc. are some of the main issues that the future wireless ad-hoc networks have to cope with. Maintaining the quality of service is critical and time varying scenarios are important and hard task to handle. Robustness is an important feature that needs to be incorporated in the future routing protocol.

2. To prove the correctness of the proposed algorithm, it needs to be implemented in other MANET routing protocols like DSDV, AODV, DSDV, and hybrid protocols. The modifications may be done as a future work.

3. The proposed algorithms prove to be efficient for moderate sized networks but for not dense networks. Also, the power threshold value for successful reception of packets by nodes are set to a fixed value. The algorithm becomes dynamic once this value is dynamically set.

4. The proposed algorithm can extend network lifetime and increase energy level balance among the nodes. There is need for modifications to decrease this metric value such as turning off the idle nodes and reducing the RREP packet storming. The future work might require to make the routing protocols considering the direction and locations of nodes.

5. In this thesis, the cross-layer interaction of MAC layer and routing layer is considered in Chapter 4, and three-layer interaction between physical, MAC, and routing layer has been considered. Future work needs to consider the five layers cross-layer interaction for providing effective routing based on the application type.