CHAPTER 2

LITERATURE SURVEY

2.1 Overview

In this chapter the related work done in the area of cross layer design for wireless networks, especially designed and developed for ad hoc networks, sensor networks and mesh networks are discussed. In the recent past these three categories of networks have been used for civilian, emergency and military applications. A lot of work has been contributed in the area of cross layer design for wireless networks. Here, the work contributed towards developing cross layer protocols for wireless networks are also discussed.

2.2 Review of Routing Protocols for Wireless Ad hoc and Sensor Networks

Routing is a challenging issue in ad hoc network since nodes are mobile and the topology of the networks is ever changing. Besides, all nodes need to communicate via wireless infrastructure. Routing metrics used such as shortest path, link quality, power conservation and position location will reduce route discovery time and also message update cost. When compared to wired networks, mobile networks have unique characteristics. In mobile networks, node mobility may cause frequent network topology changes, which are rare in wired networks. In contrast to the stable link capacity of wired networks, wireless link capacity continually varies because of the impacts from transmission power, receiver sensitivity, noise, fading and interference. In addition, wireless mobile networks have a high error rate, power restrictions and bandwidth limitations.

In Mobile ad hoc networks routing is a challenging in dynamic changing environment and has received tremendous amount of attention from researches [15, 16, 17]. This has led to development of many different routing protocols for MANETs, and each author of each proposed protocol argues that the strategy proposed provides an improvement over a number of different strategies considered in the literature for a given network scenario.

The basic routing protocols which work on table driven basis gave the initiation to the design of protocols for ad hoc networks. The overviews of wide range of routing protocols in mobile ad hoc networks are discussed. Each paper provides a performance comparison of all routing protocols and suggests which protocols may perform best in large networks [18, 19]. The routing protocols are evaluated using different network simulators [20-24] available. In addition to proactive and reactive protocols, hybrid protocols for routing were developed. Hybrid protocols are promising in providing less overhead than proactive and reactive protocols.

The security was important in wireless environment as they are vulnerable to various types of threats. The researchers thought of detecting misbehavior and malicious nodes in the ad hoc networks. The routing was done securely over the ad hoc networks by developing various secure routing protocols. Apart from this, new methods and improvements were achieved in this area. New metrics are developed and used in routing process to evaluate the protocol in a better way. More work is focused on reactive protocols such as AODV and DSR routing protocols. The AODV routing protocol was developed which yield more high packet fraction [25]. Another attempt was made with DSR routing protocol [26] with enhanced approach by proposing reactive algorithm for mobile ad hoc networks. Because of lot of development and progress in the reactive protocols, we have considered AODV, DSR and TORA are most popular protocols and used in this research work. In addition, we have also considered DSDV proactive protocol for simulation study.

There are numerous routing protocols which have been proposed for mobile ad hoc networks and there is no standard scheme that works well in scenarios with different network sizes, traffic overloads, and node mobility patterns. Moreover, these protocols are based on different design philosophies and proposed to meet specific requirements from different application domains. Thus, the performance of a mobile ad hoc routing protocol may vary dramatically with the variations of network status and traffic overhead. This comprehensive performance study with varying different parameters is carried out in our research work. The performance variations of mobile ad hoc network routing protocols make it a very difficult task to give a comprehensive performance comparison for a large number of routing protocols.

There are three different ways to evaluate and compare the performance of mobile ad hoc routing protocols. The first one is based on analysis [18] and uses parameters such as time complexity, communication complexity for performance evaluation. In the second method, routing performance is compared based to simulation results [18, 19]. Network Simulator 2 [20], GloMoSim [21], OPNET [22] and QualNet [23] are wildly used simulators. The simulation results heavily dependent on the selection of simulation tools and configuration of simulation parameters. The last method is implementing routing protocols and analyzing their performance using data from real-world implementations. This method is not suitable for comparison of large number of routing protocols. Considering the dynamic network features, metrics for evaluating performance of mobile ad hoc network routing protocols are proposed in [27]. Generally, a properly designed mobile ad hoc routing protocol should adapt to the dynamic network changes quickly with lower consumption of communication and computing resources.

In [28] four different routing protocols AODV, Temporally Ordered Routing Algorithm (TORA), DSDV and DSR are compared. It is shown through simulation results that DSR generates less routing load than AODV. AODV suffers from end to end delay while TORA has very high routing overhead. The better performance of DSR is because it exploits caching aggressively and maintains multiple routes to the destinations.

Performance comparison of AODV and DSR routing protocols in a constrained situation is done in [29]. The authors claim that the AODV outperforms DSR in normal situation but in the constrained situation DSR out performs AODV, where the degradation is as severe as 30% in AODV whereas DSR degrades marginally as 10% in constrained situations. A comparison of Link State, AODV and DSR protocols for two different traffic classes in a selected environment is done in [30]. Based on the simulation results it is observed that AODV and DSR perform well when the network load is moderate and Link State routing protocol outperforms AODV and DSR when the network load is high.

Perkins et al [31] showed the performance of two on demand routing protocols AODV and DSR. Though both AODV and DSR use on demand route discovery, they have different routing mechanisms. The authors observe that for application oriented metrics such as delays and throughput DSR outperforms AODV when the number of nodes in the network. AODV outperforms DSR when the number of nodes in the network is very large. The authors do show that DSR consistently generate less routing load than AODV.

S. Gowrishankar et al [32] compares the performance of two prominent routing protocols in MANET: Ad hoc On-Demand Distance Vector Routing (AODV) and Optimized Link State Routing (OLSR) protocol. The performance differentials are analyzed using various metrics like packet delivery ratio, end to end delay and number of nodes and are simulated using NS-2.

F. Bertocchi et al [30] made comparison of link state, AODV and DSR protocols for two different traffic classes in a selected environment. The classic Dijkstra is also reported as comparison term. As performance metric, packet delivery fraction, throughput, average delay and energy are considered. They state that AODV and DSR perform well when the network load is moderate, while, if the traffic load is heavy, simple link state outperforms the reactive protocols.

In this research work, an attempt is made to study the performance analysis of routing protocols for Wireless Ad hoc Networks. The comparison is made on the routing protocols AODV, DSR, DSDV and OLSR using Rician propagation model. This work is a base for cross layer design approach for considering routing protocols for Ad hoc and Sensor Networks.

IEEE 802.15.4 is an established set of specifications for wireless personal area networking (WPAN), i.e., digital radio connections between computers and related devices. IEEE 802.15.4 standard was designed for LR-WPANs. WPAN is an all-wireless deployment of sensor nodes, which include a sink, specifically known as PAN co-ordinator for short-range communication. Wireless sensor networks (WSN) are complex distributed systems of nodes with sensing, data processing and storage capability, wireless-communication interfaces and, in general, limited power. The network architecture is such that a virtual backbone is formed, with the PAN co-ordinator serving as the core node while other devices function as child nodes that rely on their parent, in this case the PAN co-ordinator, during network establishment and communication. This basic topology can be extended to a multi-tiered hierarchical network by electing one or more child nodes as a co-ordinator or cluster-head to manage their own WPAN. Existing discussions on WSNs, and LR-WPANs in particular, assume immobile operation of wireless sensors.

While current evaluation studies on IEEE 802.15.4 focus on 1-hop J. Zheng and M.J. Lee [33] implemented the IEEE 802.15.4 network only, this paper describes the first experiment on multihop ad hoc networks. J. Zheng and M.J. Lee [4] implemented the IEEE 802.15.4 standard on ns2 simulator and subsequently produced the first performance evaluation on 802.15.4.

The literature comprehensively defines the 802.15.4 protocol as well as simulations on various aspects of the standard. This paper has a minor evaluation on the performance of peer-to-peer networks. Other works [34, 35] focused on simple 1-hop star network. G. Lu et. al. [34] implemented their own ns2 version of 802.15.4 and studied its performance in beacon-enabled mode while J.S. Lee [35] performed a realistic experiment using hardware devices. Finally, Timmons and Scanlon [36] presented an analytical analysis of the protocol in body are networking (BAN).

This work is motivated by the tremendous potential of IEEE 802.15.4 in supporting simple, low-rate, and low-power applications for LR-WPANs. Before real time applications could be implemented, extensive performance evaluation on the standard is necessary to obtain an idea of what to expect, especially when critical issue like QoS is of concern. Therefore, several efforts on performance evaluations were conducted since the inception of IEEE 802.15.4. This work is significantly different from other existing works because it covers simulation and different topological experiments focusing on small-scale networks with seven sensor nodes, thus providing simulated as well as actual performance measurements.

2.3 Review of Cross Layer Design Based Protocols for Wireless Networks

There has been recent trend on developing energy efficient MAC protocols for wireless sensor networks [37]. They are generally based on a mechanism of turning off their radio transceivers whenever they are not involved in transmission. They mainly focused on how to optimize the MAC layer's energy efficiency without fully exploiting the potential synergies of the interaction among different layers. The provision of energy-awareness resides next to the reduction of energy consumption by the nodes. To accomplish that, a MAC protocol must reduce collisions, overhearing, control packet overhead and idle listening. The last factor is especially significant, as nodes often need to hear the channel for possible reception of data, like in the 802.11 family of protocols. The research group of the CROSS MAC showed that the consumed energy ratios are 1:2:2.5 for idle listening: reception: transmission, respectively [38]. As WSNs need to support applications for long periods of time, sensor nodes must "sleep" for as long as they can. The trade-off between minimized energy consumption and deterioration in delays, throughput and efficiency is clear and different from the CROSS MAC family of protocols, where bandwidth utilization is the primary target. A power-save mode, such as the one used in CROSS MAC, is necessary but in WSNs a more aggressive policy is needed to ensure maximum energy conservation.

In this research work, we instead follow a cross-layer design approach and propose a new MAC protocol framework that utilizes routing policy information from the network layer. This increases the overall performance gain in terms of energy efficiency which be maximized. The basic idea of the proposed Cross Layer MAC is to minimize the number of nodes that are supposed to wake up when their NAV (Network Allocation Vector) value expires. Remind that, by using NAV information of RTS/CTS packets sent by a data source and a destination, a shared wireless medium can be reserved during the time for exchanging their data packets. Other nodes except for these two communicating nodes are supposed to enter a sleep mode, which is very good for saving their energy sources. An efficient MAC protocol for WSNs should minimize collisions and give priority to the reduction of the nodes' energy consumption, thus prolonging network lifetime. MAC protocols should also provide reduced latencies, high throughput and bandwidth utilization.

There have been several research approaches of combining cross layer idea into the WMN routing protocol design. The idea has increased the utilization of the network resources to a greater extent and enhanced the guarantee quality of services. In recent study [39], cross layer based proactive routing protocol CL-OLSR based on OSLR routing protocol for WMN is proposed. The protocol exploits a brand new routing metric called Cross Layer Metric (CLM) was used and it takes four impact factors into consideration. The node available bandwidth, load on the node, delivery rate and link interference were taken into account through cross layer operation mechanism for route calculation. The effect of route selection is optimized and network performance is drastically improved. Simulation experiment results demonstrate that CL-OLSR dramatically improves the network performance, efficiently increases the network throughput, reduces the end-to-end average delay, and achieves load balancing route results.

Cross layer optimization schemes and algorithms between different protocol layers are investigated with an objective of shedding light on open research problems and new approaches are covered in [40]. In this work, authors feel that even though there are many cross layer design schemes shows greater performance through simulations or prototypes but when it comes to actual implementation they face several complexities in modifying the protocols in different layers. These modifications can impact the maintainability of the software, stability of different protocol modules, and flexibility of porting codes to different platforms. They also found that the standard working mechanism in the protocol stack is broken and cross layer design can be easily be incompatible with other networks and thus, the interoperation between difficult networks is difficult to maintain. In case of layered protocol architecture, protocols in one layer can evolve separately without disrupting the functionalities of protocols in another layer. The upgrade or change in protocols must be coordinated among different protocol layers when cross layer design is adopted.

Capacity aware routing (CAR) protocol which adopted a routing metric called bottleneck link capacity was proposed in [41]. This metric can increase the network throughput and reduce the end-to-end delay to a certain degree by the cross-layer operation of considering the link interference, the link load, and other link quality information. QoS-aware routing with a congestion control and load balancing protocol (QRCCLB), which by introducing the cross layer operation considering dynamic source routing protocol in Ad hoc network as the prototype and making the network traffic bypass the networks business was proposed in [42].

In [43], a wireless fidelity Ad hoc on-demand distance vector (Wi-Fi-AODV) routing protocol was proposed, which fully exploits the adaptive rate switching mechanism of IEEE 802.11 by introducing the cross-layer mechanism, in which nodes use the data transmission rate of the physical layer as a metric and are able to establish a route with a high data rate and low transmission delay.

The cross layer design to provide frame delivery rate, extra bandwidth, and the node load of the media access control (MAC) layer for the network layer routing algorithm was proposed with an integrated metrics based extended dynamic source routing method (EDSR) in [44]. This improves the throughput rate and load balance capability of the network and satisfying users' QoS requirements by promoting the network's overall performance. These routing protocols are all proposed based on existing on-demand routing protocols of Ad hoc network, such as dynamic source routing, and Ad hoc on-demand distance vector routing. But for WMN, the network node is relatively fixed. There was no recent reactive or protocol was considered for performance study. Only node failures, as well as joining, leaving, and the uncertainty of wireless links will result in changes in the network topology. The change rate of network topology is far below the arrival rate of the data flow and the main business in WMN is the Internet business with certain delay requirements. These routing protocols have jumped out of the traditional route of taking the minimum hop as the routing metric and introduced the idea of cross-layer design. But there is a lack of systemic knowledge for the cross-layer design of WMN, in which the implementation process is complex and the practicality is low.

2.4 Problem Statement and Formulation

Ad hoc Sensor and Mesh networks have emerged recently as an important trend of future wireless systems. The evolving wireless networks are seriously challenging the traditional OSI layered design. The three main layers such as physical, MAC and network layer do impose much performance penalty in case of wired networking applications. In case of wired links, layers are independent of each other and do not affect the performance of each other. But wireless networks links can no longer be viewed as separate entities, since performances are independent of each other. As a consequence of the independency, there is a need for a more complex medium access medium. There is a need of mechanism to control the amount of interference experienced by receivers. In order to provide high capacity wireless access and support new multimedia network, the various OSI layers and network functions should be considered together while designing the network.

2.4.1 Problem Statement

"To Implement Cross Layer Design Techniques for Wireless Networks, especially for Ad hoc, Sensor and Mesh Networks with respect to network layer and Optimize and Analyze the Performance of developed protocols using standard network parameters under different traffic patterns, network conditions and scenarios".

2.4.2 Problem Formulation

In this research work, the various performance optimizations and certain design challenges of wireless networks especially ad hoc networks, sensor networks and mesh network using cross layer design has been designed and developed by building experimental setup. The present work aims at the following:

- To study the behavior of interlayer communication by optimizing the network protocol stack
- To conduct exhaustive experiments on traffic patterns, user locations, network conditions which are constantly changing
- To Analyze the Impact of energy and delay constraints change on the design principles cross all layers of the protocol stack
- To study the performance of routing protocols and develop congestion-aware cross layer system

The above sequence of simulation experiments was carried out systematically and the details of the simulation parameters, traffic pattern, results and discussion are given in the ensuing chapters.