CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

The routing algorithms for MANET are inherited from conventional algorithms which are subject to much criticism as they do not consider ad hoc network characteristics such as mobility and resource constraints. As routing plays an important role for the reliability of an ad hoc network many routing methodologies have been proposed. Proactive routing protocols discover routes for every pair of nodes by continuously updating the routing tables at fixed time intervals irrespective of data traffic between source and destination. A route is available immediately when communication is to be established between a source and destination. Proactive routing protocol based wireless networks have additional overheads in the network due to constant updation of route traffic but end to end delay is minimized. On the other hand reactive routing protocols establish a route to destination only when there is a requirement. Though, the network control packet overheads are reduced in reactive routing protocol, the end to end delay increases due to the route discovery process by Alandzi and Quintero (2007). Popular reactive routing protocol include AODV routing by Perkins et al (2002), DSR by Johnson et al (2001), ABR by (Toh 1997) and some of the proactive routing protocols include DSDV routing by Perkins et al (1994), OLSR by Clausen and Jacquet (2003) and Fish Eye State Routing (FSR) by Pei et al (2000).
In this chapter, works available in the literature related to ad hoc network routing protocols, AODV routing, proactive, reactive and hybrid routing protocol, comparison of the protocols, link quality based routing protocols and swarm intelligence based routing are reviewed.

2.2 AD HOC NETWORK ROUTING PROTOCOLS

There are many works on the ad-hoc network routing protocols found in literature by Corson et al (1995), Krishna et al (1997) and Bhorkar et al (2009). In some of the earlier works, Krishna et al (1997) proposed a new methodology for routing and topology information maintenance. The routing protocols then prevalent used distributed algorithms for finding shortest paths in weighted graphs. The proposed methodology was based on algorithms proposed for cluster creation and maintenance. The algorithm divides the graph into a number of overlapping clusters; thus, the clusters formed in the graph are cluster-connected. Routing is done by node to node inside cluster and due to overlaps cluster to cluster. Any change in the topology of the network is reflected on the cluster membership. Each node maintains a list of neighbors, a cluster list of all the clusters in the network and a boundary list which contains the nodes in overlaps. Routing table is generated using the cluster list and boundary list information. Any change in topology is updated in the cluster list and boundary list. Experiments showed that the proposed methodology achieved performance improvements by reducing routing overhead when compared with previous approaches.

Corson et al (1995) presented a loop-free, distributed routing protocol for mobile packet radio networks. The protocol was designed for networks, which does not change too fast or near-static networks. The objective of the routing algorithm was to build routes only when necessary and to build them quickly before topology changes. When no global topological knowledge is available, the algorithm adapts in a distributed
fashion to the arbitrary changes in topology. The proposed protocol maintains source-initiated, loop-free multipath routing only to desired destinations. Thus, the overhead is reduced even in a varying topology. Experiments measured end-to-end packet delay and throughput of the proposed algorithm under different scenarios and was compared with that of pure flooding based algorithm. The results indicate that the proposed protocol generally outperforms the alternative protocol at all rates of change for heavy traffic conditions.

2.2.1 Ad Hoc On Demand Distance Vector (AODV) Routing

The AODV algorithm allows dynamic, self-starting, multihop routing between all mobile nodes participating in a wireless ad-hoc network by Perkins et al (2003). AODV enables mobile nodes to receive routes to the desired destination very fast. It does not require the nodes to maintain the routes that are no longer needed in a current communication. AODV allows the nodes to respond very quickly to link breakages and changes in network topology. The operations of AODV are all loop-free, and offer fast convergence when the ad-hoc network topology changes by avoiding the Bellman-Ford ’counting to infinity’ problem. Typically, this means when a node changes its position within the network. When link breaks, AODV notifies all the concerned nodes so that they are able to avoid and invalidate the routes using this lost link.

Routing Table: Each node in AODV contains a routing table, the routing table contains

- Destination
- Next hop
- Number of hops to reach destination
- Destination sequence number
- Active neighbors for this route
- Route table entry expiration time

The expiration time depends on a parameter called active route timeout; it is reset every time the route has been used. The routing table is updated by using a series of control messages to determine and maintain routes.

**Control messages**: The different kinds of control messages used by this protocol are Route Request (RREQ), Route reply (RREP), Route Error (RERR) and Hello messages.

**RREQ**: is a request message used when a source node wants to send data to a destination node and route is not available, it floods the network. The RREQ message format is shown in figure 2.1.

<table>
<thead>
<tr>
<th>Source address</th>
<th>Request ID</th>
<th>Source Sequence No.</th>
<th>Destination Address</th>
<th>Destination Sequence no.</th>
<th>Hop count</th>
</tr>
</thead>
</table>

**Figure 2.1 RREQ Message Format**

The request ID for each RREQ is unique, the node on receiving the RREQ checks the ID and if it had already received a RREQ in the same ID it will discard the request. Each node on receiving the RREQ updates the reverse route in the routing table to the source node. If the intermediate node does not carry valid route information in its routing table to the destination node, it rebroadcasts the RREQ. The number of RREQ messages that a node can send per second is limited.
**RREP**: is a route reply message. When the RREQ arrives at the destination node, a reverse route is created or updated in routing table and a RREP is sent along the reverse route. The intermediate node on the reverse route updates the forward route to the destination node and passes along the RREP. The RREP message format is shown in figure 2.2.

![Figure 2.2 RREP Message Format](image)

The source code on receipt of RREP, on updating the path, starts communication.

**RRER**: In AODV the route maintenance is done by each node monitoring their neighbor and RRER is generated whenever a node in an active route is not available. The RRER is sent to notify the neighboring nodes the loss of link and new route to destination is sought out.

**HELLO messages**: Nodes use HELLO messages to continuously monitor the local connectivity with other neighboring nodes that is the nodes it can directly communicate. The hello messages are never forwarded.

**Sequence numbers**: helps keeping the route information fresh; outdated and unnecessary information are removed from the network. Sequence numbers prevent looping and also act as timestamp. The routing table stores the sequence number of all the destination nodes, and updates whenever it receives the message with a greater sequence number.
Active Route Timeout (ART): ART is the time until which the node removes the route state from the routing table. ART is the time at which the route is considered invalid.

Richard et al (2005) studied AODV active route timeout for routing. This does not consider either actual path lifetime or time scale correlation between two successive connections of same end-points. Locating optimal value needs a balance between a short ART that starts a new route discovery when a valid route is available and a long ART which is risky to forward packets on an invalid route. In the first, new route discovery initiation is the avoidable cost and in the second it is loss of one or more packets and a RERR initiation process instead of a new route discovery without packet loss. Timeout and link layer RERRs are required to find ART optimal value. RERRs latency stem from unavoidable delay between sender and nodes towards the receiver. The above trade-off is focused on and defines a route errors taxonomy which enables characterization of optimal ART value.

Preliminary results were obtained by NS-2 simulations with the experiment consisting of a 100 node network spread over 1400 x 1400 sqm and moving according to the Modified Random Waypoint Model. Static and dynamic nodes simulations were conducted. In dynamic scenario, nodes moved at speeds of 10 m/s and 20 m/s (36 Kmph, 72 Kmph). Simulation results led to the conclusion of an optimal ART value suggesting that the ART parameter be made a dynamic parameter function of node mobility.

Vadde and Syrotiuk (2004) applied techniques from experiments, designs, and analysis to show timers effect on response variables and to identify factor interactions involving AODV timers. Routing protocols use timers to respond to network dynamics caused link failure. Despite their importance, timer’s duration is set in a trial-and-error manner. The new methodology applied Design Of Experiments (DOE) and analysis techniques.
This study plans to identify protocol interactions at different layers of a protocol stack, and also factors within a protocol which interact and affect performance in a soft-state context in AODV. Simulations were conducted with 30 mobile nodes with statistical analysis being used to analyze simulation results which concluded that:

- Packet arrival rate contributes almost 30% to the number of RREQs generated.

- Long values for the timer may cause intermediate nodes to generate and forward intermediate RREPs to other nodes requesting a route to the same destination in spite of a broken link. This leads to route establishment delay as when the source node learns of the false route it restarts route discovery.

- Node speed is a major factor (79%) for delay. As node speed increases, frequent link breaks occurs causing routes reestablishment. This increases the delay for data packets.

The performance of AODV routing protocol is investigated for effect of active route timeout for nodes which move in constant speed ranging from 10.8 to 90 Kmph. Experiments are conducted for varying ART to find optimal time.

The AODV routing protocol saves storage space and energy. AODV does not need a central administrative system to control routing process. Hello messages used for maintenance do not cause large overhead in the network. Topological changes in the network are fast as updates happen at only the affected nodes. AODV can be used even in low processing and low bandwidth utilization. The disadvantages are its latency and scalability.
Various enhancements have been proposed using AODV protocol. An improved AODV for load balancing have been proposed by Rani and Dave (2007) for route discovery using aggregate interface queue length. AODV-BRL was proposed by Yujun and Lincheng (2010) to increase the adaptation of routing protocols to topology changes by enhancing AODV-BR.

One of the most representative features of the AODV protocol is the use of the Destination Sequence Number (DSN), created by the destination for each route entry in the routing table of each node participating in the ad-hoc network. The destination sequence number is created by the destination and will be included along with route information the destination sends to a requesting node. Using the destination sequence numbers guarantees loop-free routes and is easy to implement. When several routes are available to a destination, the requesting node selects the route with the highest sequence number.

The AODV routing protocol is created for mobile ad-hoc networks with tens to thousands of participating mobile nodes. AODV can effectively be used for low, moderate, and relatively high mobility rates, as well as a variety of data traffic levels. AODV is formed for networks where the nodes can all trust each other, either by the use of preconfigured keys, or because it is known that there are no malicious intruder nodes in the network. AODV has been modeled to minimize the propagation of control traffic and prevent overhead on data traffic, in order to enhance both, the scalability and the performance of ad-hoc networks.

Perkins and Royer (2003) proposed AODV, a novel algorithm for the operation of ad-hoc networks. The routes are obtained as required or on-demand with no dependence on periodic advertisement. The proposed routing algorithm is ideal for dynamic self starting network, as required by the users. The nodes in the network operate as routers when necessary. The proposed
AODV provides loop-free routes. Broken links are repaired and data packets get bypassed through different routes during repairs. As global periodic routing advertisements are not required, overall Bandwidth (BW) demand to the mobile nodes is less. However, the proposed algorithm maintains all the advantages of basic distance vector routing mechanisms. Simulation results show that the proposed algorithm can scale to big networks with large populations of mobile nodes. The proposed method was evaluated using simulation and the results verify the performance of the proposed algorithm.

Song et al (2003) proposed an extension of the AODV routing protocol for MANET. The proposed protocol LB-AODV uses concept of load balancing to limit the amount of routing control packets. The mobile nodes were logically divided into different groups to reduce and distribute the routing traffic over the network. The number of source nodes was balanced in the group accomplishing load-balancing. The performance of the proposed LB-AODV was compared with AODV, gossip-based routing protocol. Simulation results show that LB-AODV delivers more data packets to the gateway and decreases the end-to-end delay of packets delivered by reducing the transmissions of routing control messages by 50% or more. In scenarios with traffic congestion, LB-AODV significantly outperforms AODV and GOSSIP1 routing protocols.

Tauchi et al (2005) proposed a new route maintenance algorithm based on AODV. The proposed algorithm detects link break on the upstream of an intermediate node based on received radio, overlap of routes, battery and density. The algorithm avoids route breaks on detection of link breakage and re-establishes a new route before the route break. On simulations, the proposed route maintenance algorithm decreased number of route breaks, decreased end to end delay. The packet arrival ratio increased compared to
conventional method. Results from simulation shows that the proposed algorithm is more effective than AODV.

Kim et al (2006) proposed a reverse AODV which tries multiple route replies. AODV is the most commonly used and extensively researched on-demand ad hoc routing protocol. The highly varying topology of the mobile ad hoc networks is due to the mobility of the nodes. AODV in highly dynamic networks have less than efficient performance due to the routing protocols use of the single route reply along the reverse path. The route replies do not reach the source nodes, especially in high speed mobility networks. The communication delay and power consumption increases in such a scenario with the packet delivery ratio declining. The proposed algorithm, based on AODV addresses this problem by multiple route replies. The proposed extended AODV is called Reverse AODV (R-AODV), reduces the path fail correction messages and achieved more efficient performance when compared to AODV and other protocols. The proposed R-AODV protocol is implemented into simulation models using NS-2. The simulation model studied the performance metrics such as packet delivery ratio, power consumption and communication delay of the proposed algorithm and AODV. Simulation results showed that the reverse AODV achieves a better packet delivery ratio, and lessens power consumption and communication delay.

Tomar et al (2009) proposed an algorithm for selective flooding in place of broadcasting based on the AODV algorithm. The proposed algorithm reduces the routing packet overhead. In first phase three protocols DSDV, DSR and AODV were compared on performance basis, which was based on various parameters concerned with network. In second phase, a correction in AODV was proposed and implemented. This correction solves the low bandwidth problem in ad-hoc networks though with an increase in delay. The increase in delay does not hamper the usual operation of the network and
delivery of the packets. The overall performance of the network is improved in terms of throughput and delivery rate, which was the objective of the proposed modification. The primary emphasis was given on bandwidth as scarcity of bandwidth is day to day phenomena and has to be taken care due to air interface constraints for the wireless networks.

Lee and Gerla (2001) proposed an on-demand routing scheme called Split Multipath Routing (SMR) that establishes and utilizes multiple routes of maximally disjoint paths. On-demand routing is widely developed in bandwidth constrained mobile Wireless Ad Hoc Networks because of its effectiveness and efficiency. Most proposed on-demand routing protocols however, build and rely on a single route for each data session. Whenever there is a link disconnection on the active route, the routing protocol must perform a route recovery process. In QoS routing for wired networks, multiple path routing is prevalently used. However, multiple routes are not well-suited for ad hoc networks as it is constructed using link-state or distance vector algorithms. The proposed protocol establishes and utilizes multiple routes of maximally disjoint paths. Providing multiple routes helps minimizing route recovery process and control message overhead. The proposed protocol uses a per-packet allocation scheme to distribute data packets into multiple paths of active sessions. This traffic distribution efficiently utilizes available network resources and prevents nodes of the route from being congested in heavily loaded traffic situations. The proposed SMR was evaluated for the performance using extensive simulation.

Marina and Das (2001) developed an on-demand multipath distance vector protocol for mobile ad hoc networks. The proposed algorithm is based on AODV and is referred to as Ad hoc On-demand Multipath Distance Vector (AOMDV). The proposed protocol creates paths that are multiple loop-free and link-disjoint. Advertised hop count is used for finding loop-free paths and
link-disjointness of the multiple paths is obtained through a form of flooding. The ns-2 simulation platform is used to compare the performance of the proposed algorithm AOMDV with AODV. Simulation results showed that the proposed algorithm achieved significant improvement in the end-to-end delay and the routing overhead is reduced by around 20%.

Sanzgiri et al (2002) proposed authenticated routing for ad hoc networks. The security of the network is not focused upon in the routing protocols. The study details upon the various security threats against ad hoc routing protocols. The ADOV and DSR are examined in depth, and three distinct security requirements were identified. The proposed routing algorithm gives a solution to one of the requirements. In a managed-open scenario where network infrastructures are not pre-deployed, but a small amount of earlier security coordination is expected. The proposed protocol is Authenticated Routing for Ad hoc Networks (ARAN). It is based on certificates and secures the network successfully against all identified attacks.

Xue et al (2003) have proposed a QoS framework for MANETs Adaptive Reservation and Pre-allocation Protocol (ASAP). By using two signaling messages, ASAP provides fast and efficient QoS support while maintaining adaptation flexibility and minimizing wasted reservations. Simulation of this proposed framework was done using AODV; the simulation illustrated the features and performance of ASAP, and demonstrates the design concepts.

Schumacher et al (2006) have approached the problem of load balancing for wireless multihop networks by distributed optimization. They have used an approximation algorithm for minimizing the maximum network congestion and implement it as a modification of the DSR routing protocol. The algorithm was based on shortest-path computations that are integrated
into the DSR route discovery and maintenance process. Therefore, it does not rely on the dissemination of global information within the entire network.

Tran and Raghavendra (2006) have proposed CRP a congestion-adaptive routing protocol for MANETs. CRP enjoys fewer packet losses than routing protocols that are not adaptive to congestion. This is because CRP tries to prevent congestion from occurring in the first place, rather than dealing with it reactively. A key in CRP design was the bypass concept. As bypass is removed when the congestion is totally resolved, CRP does not incur heavy overhead due to maintaining bypass paths. The bypass maintenance cost was further reduced because a bypass is typically short and a primary node can only create at most one bypass.

Chen et al. (2007) have proposed a congestion-aware routing protocol for mobile ad hoc networks which uses a metric incorporating data-rate, MAC overhead, and buffer delay to combat congestion. This metric was used, together with the avoidance of mismatched link data-rate routes, to make mobile ad hoc networks robust and adaptive to congestion.

Yu et al. (2007) have proposed a Link Availability-Based QoS-aware (LABQ) routing protocol for mobile ad hoc networks based on mobility prediction and link quality measurement, in addition to energy consumption estimate. Their goal was to provide highly reliable and better communication links with energy-efficiency. Their routing algorithm has been verified by NS-2 simulations and the results have shown that LABQ outperforms existing algorithms by significantly reducing link breakages and thereby reducing the overheads in reconnection and retransmission. It also reduces the average end-to-end delay for data transfer and enhances the lifetime of nodes by making energy-efficient routing decisions.
Li et al (2012) proposed Fuzzy Velocity-based AODV (FV-AODV) for improving the reliability and the effectiveness of AODV in MANET. In AODV, numerous control messages are used to construct and maintain a reliable route. However, these messages consume a large quantity of the network resources, and thus the effectiveness of AODV is reduced. The proposed FV-AODV adaptively adjusts the HELLO_INTERVAL, according to the velocities of the nodes. The transmission time interval of HELLO message is adjusted to improve the reliability and the effectiveness of AODV. The performance of FV-AODV is evaluated in terms of control overhead, the number of HELLO messages, and delivery ratio. Simulation results demonstrate that FV-AODV achieves a better trade-off between the reliability and the effectiveness than AODV.

2.2.2 Proactive, Reactive and Hybrid Routing Protocol

Guo and Malakooti (2007) presented efficient routing metric prediction methods. The routing metrics of delay and energy cost were predicted using double exponential smoothing. Heuristic based on normal-like distributions were used to predict link stability metric in mobile ad hoc networks. The routing metrics predictions are integrated with regular routing information exchanges. Modified Dijkstra’s algorithm was used to construct routing table on each node to evaluate the predicted metrics values. The multi-metric prediction and evaluation was incorporated with OLSR and named as OLSR_MC. Simulation shows that OLSR_MC is more adaptive to the network dynamics. OLSR_MC improves performance considerably on multiple routing objectives, including higher packet delivery ratio, shorter average end-to-end delay, and prolonged network energy lifetime.

Ramakrishnan et al (2007) proposed a new method of Dynamic Reconfigurable Routing (DRR) using two reactive on demand protocols, DSR and AODV. The proposed router observes the throughput and on the decrease
of throughput below certain acceptance value, it adapts different protocol to maintain the throughput. Simulation tests showed that the DRR protocol chooses the best protocol at every instant and always maintains a high throughput. The performance plot got from the simulation tests indicate that DRR routing protocol maintains all time high throughput against fluctuating network parameters such as maximum mobile speed, number of nodes, size of packet, and terrain dimensions.

Kalaavathi and Duraiswamy (2008) proposed Ant Colony based Node Disjoint Hybrid Multi-path Routing (ACNDHMR) a hybrid routing protocol based on AntHocNet routing algorithm that establishes multiple node disjoint routes between a source destination pair and switches between the routes based on a heuristic. A virtual class room is one that can be established by using mobile devices and whose members can be dynamically added or removed. The implementation of virtual class room for lesson handling and query discussion using mobile ad hoc network is analyzed. The data are spread among the N (here N = 3) node disjoint routes from the beginning of the data transmission session. The performance metrics, average end-to-end delay, packet delivery ratio and load balancing have been analyzed for various pause times. The average end-to-end delay and packet delivery ratio have not varied significantly. Optimal load distribution is achieved by spreading the load among different node disjoint routes. The experimental results indicate that ACNDHMR outperforms AntHocNet because multiple routes provide robustness to mobility. The performance difference becomes evident since the load is distributed evenly to all the nodes, which helps in network stability.

Bhorkar et al (2009) proposed a distributed opportunistic routing scheme ‘d-AdaptOR’, for multi-hop wireless ad-hoc networks. A reinforcement learning framework is used in the proposed scheme to achieve optimal performance adaptively. Optimal performance is achieved even in the
absence of reliable knowledge about network model and channel statistics, and d-AdaptOR functions using local information and coordination with other nodes via network message passing. The proposed adaptive routing maximizes the expected average per packet reward from source to destination. Simulation results show that the proposed scheme outperforms the existing opportunistic protocols.

A Novel Constrained Entropy-based Multipath Routing (NCEMR) algorithm proposed by (Chunhua 2009) in MANET. New metric-entropy is constructed using the proposed algorithm. This metric-entropy helps reduce route reconstruction due to which QoS guarantee is provided to the network. This is done to increase the reliability of data transmission or to provide load balancing. The simulation results show that the proposed approach and parameters provide an accurate and efficient method of estimating and evaluating the route stability in dynamic Ad Hoc. These analytic results provide insights into the mechanism of the multipath routing protocol.

2.2.3 Comparison of Routing Protocols

Das et al (2000) compared the performance of two prominent on-demand routing protocols for mobile ad hoc networks: DSR and AODV routing. Dynamic topology and multihop wireless connectivity are the norm for ad hoc networks. A detailed simulation model with Media Access Control (MAC) and physical layer models is used to study interlayer interactions and their performance implications of the DSR and AODV. It was demonstrated through simulation that even though DSR and AODV share similar on-demand behavior, there is marked difference in performance due to the differences in the protocol mechanics. The performance differentials are analyzed using varying network load, mobility, and network size. Based on the observations, recommendations to improve performance of the protocols were discussed.
Cano and Manzoni (2000) presented a performance comparison of the DSR, AODV, TORA and DSDV routing protocols with respect to energy consumption, evaluating how the different approaches and algorithms affect the energy usage in mobile devices. The design of efficient routing protocols is a fundamental problem in a MANET. Many different protocols have been proposed in the literature, each one based on different characteristics and properties. Some of these protocols have been studied and their performances have been evaluated in detail - focusing on aspects like routing overhead, latency and route length. In this work, the energy consumption issues of the routing protocol are studied. The performance comparison of the DSR, AODV, TORA and DSDV routing protocols with respect to energy consumption was evaluated using different approaches and algorithms was studied.

Mbarushimana and Shahrabi (2007) evaluated the performance of reactive (AODV, DSR) and proactive (OLSR) routing protocols in MANETs. The routing protocols were compared for performance under CBR traffic with different network conditions. Generally, studies reported in the literature, evaluate the performance of the proposed routing algorithms. With the publication of experimental standards of routing protocols by IETF, no major study was conducted to compare the performance of reactive against proactive protocols. The study evaluates the performance of reactive (AODV, DSR) and proactive (OLSR) routing protocols in MANETs under CBR traffic with different network conditions. The experimental results showed that contrary to previous studies, proactive routing protocols achieve better performance than reactive protocols in routing traffic at the cost of a higher routing load.

2.2.4 Performance Metrics

Chan et al (1997) proposed modification to the TCP, which uses negative acknowledgment as an explicit notification for packet corruption.
The congestion control policy of the TCP works well today over a wide range of networks. However, if a TCP connection consists of erroneous links, degradation in throughput and delay performance can be significant. Analysis on the TCP window dynamics is done to determine the end-to-end throughput of a TCP connection with a wireless link and to demonstrate the impact of high error rate in a wireless environment. To improve the performance of the TCP in a wireless environment, a simple modification to the TCP, which uses negative acknowledgment as an explicit notification for packet corruption is proposed. The performance of the proposed “NACK”-based scheme is compared with an existing modified version, LHACK, for both binary and Rayleigh fading channels.

Chen et al (2003) proposed an adaptive Congestion Window Limit (CWL) fin setting strategy to dynamically adjust TCP’s CWL according to the current RTHC of its path. The study presents on the solution for correct setting of TCP’s CWL to achieve optimal performance. Previous studies in literature conclude that using a small CWL improves TCP performance in certain scenarios. The study links the setting of TCP’s optimal CWL with identifying the bandwidth-delay product (BDP) of a path in MANET. The experiments proved that independent of the MAC layer protocol being used, the BDP of a path in MANET cannot exceed the round-trip hop-count (RTHC) of the path. The study further shows that in a chain topology, a tighter upper bound exists, which is approximately 1/5 of the RTHC of the path. The proposed adaptive CWL setting strategy to dynamically adjust TCP’s CWL according to the current RTHC of its path is based on this tighter bound. The ns-2 simulations show that the proposed strategy improved the TCP performance by 8% to 16% in a dynamic MANET environment.

The work aimed at improving performance of in internet connectivity by the application of local congestion methods in routing
protocols was proposed by Tomar (2008). The proposed method increases the packet delivery ratio of AODV even in constrained conditions to a satisfactory level, which has been major concern in the routing algorithm in mobile ad hoc networks. The experimental results show significant improvement in normalized routing load and end to end delay. The numerical results showed up to 27% improvement over existing algorithms. Using local repair algorithm the AODV performance was increased by 4.4%.

Abouzeid et al (2000) presented an analytical framework, TCP-R, for modeling the performance of a single TCP session in the presence of random packet loss. A Markovian approach is developed that allows to study both memoryless channels (i.i.d packet loss) and channels with memory (correlated packet loss) modeled by a two state continuous time Gilbert model. The analytical results are validated against results using the ns simulator. It is shown that the model predicts throughput for LANs/WANs (low and high bandwidth delay products) with good accuracy. Further, throughput for the i.i.d loss model is found to be relatively insensitive to the Probability Density Function (PDF) of the loss inter-arrival process. For channels with memory, an empirically validated rule of thumb to categorize the channel transition frequency was presented.

Mirza et al (2007) presented a new, lightweight method for TCP throughput prediction that can generate accurate forecasts for a broad range of file sizes and path conditions. The proposed method is based on Support Vector Regression modeling that uses a combination of prior file transfers and measurements of simple path properties. The capabilities of the throughput predictor is calibrated and evaluated in an extensive set of lab-based experiments where ground truth can be established for path properties using highly accurate passive measurements. The performance for the proposed method in the ideal case of using passive path property measurements over a
range of test configurations was reported. Experimental results show that for bulk transfers in heavy traffic, TCP throughput is predicted within 10% of the actual value 87% of the time, representing nearly a 3-fold improvement in accuracy over prior history-based methods. In the same lab environment, the proposed method is assessed using less accurate active probe measurements of path properties, and show that predictions can be made within 10% of the actual value nearly 50% of the time over a range of file sizes and traffic conditions. This result represents approximately a 60% improvement over history-based methods with a much lower impact on end-to-end paths. A predictor tool called PathPerf was implemented and tests were conducted on wide area paths. The results demonstrate that PathPerf predicts TCP throughput accurately over a variety of paths.

Goyal et al (2002) derived analytic models that predict the performance of TCP flows between specified endpoints using routinely observed network characteristics such as loss and delay. The ultimate goal of the proposed approach is to convert network observables into representative user and application relevant performance using non-invasive network samples to predict the throughput of representative TCP flow between given end-points. The selection and transformation of network data into metrics based on the predicted throughput of long lived TCP flows is investigated. The main contributions of this paper are two-fold. Firstly, the ways to sample the network to obtain reliable and accurate estimates of important network characteristics like Round-trip time (RTT) and loss rates was investigated. In this respect, it is important to understand how and when network observables are good estimators of TCP session observables. This is important as even the most accurate TCP model will be rendered ineffective if the required input parameter values cannot be determined accurately. The second contribution is the development of a model capable of predicting steady state TCP throughput reasonably accurately, using only the input parameters that can be easily
obtained in a non-invasive fashion. The model was evaluated for a wide range of configurations using both test bed experiments and simulations and found to predict steady state TCP throughput reasonably well, at least in scenarios where the network monitoring information available to the model was itself reasonably accurate.

### 2.3 LINK QUALITY BASED ROUTING PROTOCOLS

As MANET’s network topology and environment change quickly, communication quality too varies with time. Link quality prediction can mitigate link quality degradations by pro-actively adapting a network to an operating environment. Numerous simulations have revealed that link quality prediction is a mandatory requirement for ad-hoc network routing. In wired networks, shortest distance criterion chooses optimal routing paths. But a more sophisticated method is required for route optimization in Wireless Ad Hoc Networks due to a significant number of failures. Link quality prediction algorithms were categorized as deterministic approaches by Su et al 2001, Goff et al (2001) and Qin and Kunz (2004) which provide a precise link quality value and stochastic approaches by Gerharz et al (2002), Jiang et al (2001) which deliver a probabilistic measure. Both approaches explicitly or implicitly employ a deterministic signal propagation model.

On-demand routing protocols which initiate route discovery for active paths, reduce traffic on shared low bandwidth channels. When a path breaks, multiple timeouts lead to a costly high latency. Link quality prediction enabled proactive route discovery is used by Su et al (2001), Goff et al (2001) and Qin and Kunz (2004) to mitigate this problem by initiating route discovery prior to path breaking thereby reducing both packet loss and jitter. Link quality prediction can also cluster the network dynamically into stable node groups reducing update propagation network topology time changes by McDonald and Znati (1999).
Agarwal and Sulabh (2000) proposed routing algorithm, Route-Life
etime Assessment Based Routing protocol (RABR), including residual-
route-lifetime prediction based on affinity appraisal. Added to this, the
protocol considered path length when selecting an optimal TCP source route.
DSR, DSDV and AODV fail to include node connectivity assessment as route
selection basis. RABR algorithm predicts topology changes through provision
of a quantitative measure calculated on signal strength information basis. An
affinity parameter assesses residual link life. The NS simulator has been
modified to incorporate both Signal Strength Adaptive (SSA) protocol and the
suggested RABR protocol. Ad hoc routing protocols simulations were run on
25 mobile nodes and results for pause times range and mean node speed which
were presented showed that RABR protocol outperformed existing routing
protocols for medium to large average node speeds.

Gunes et al (2002) suggested for MANETS a new on-demand
routing algorithm, Ant-colony-based Routing Algorithm (ARA), to locate
paths between communication end points when aggravated through node
mobility. Based on swarm intelligence and on the ant colony meta-heuristic
the protocol attempts to map swarms solutions to mathematical/engineering
issues. This is a highly adaptive, efficient and stable protocol which aims to
reduce routing overheads through integration of connection/link quality into
pheromone concentration computation, specially the evaporation process.

Ad hoc wireless routing protocols presently choose shortest-path or
minimum hop count routes to destination. But such routes selected on the
erlier mentioned parameter include longer hop–length links with bad signal
quality. Elimination of routes with bad links is expected to improve routing
protocols. Tsai et al (2006) modified the AODV routing protocol to avoid bad
quality link routing. The suggested method integrated hand-off concept into
the protocol to avoid link breakage during route maintenance. The OPNET
simulation results were promising, revealing that the new protocol introduced a much lower routing overhead but still provided equal or better performance than the original AODV protocol with regard to delay and throughput.

A very tough problem in QoS routing in MANET is ensuring that established path continues linkage without breaking till data transmission is completed. To reduce broken routes number by Dana and Babaei (2011) suggested a new routing algorithm using fuzzy applications for improved reliability during route selection. The suggested algorithm source chooses a stable path for nodes mobility through consideration of node position/information velocity. To achieve this, source estimate Route Stability Coefficient (RSC) combines with fuzzy logic to choose a route with good stability for the required source-destination pair. A new route maintenance suggested in this protocol included destination initiating route recovery and source switch to a stable path to avoid potential path breaks later. Simulation proved that the algorithm reduced broken routes significantly, improved route stability and increased network performance.

Wireless Ad Hoc Networks performance is improved by link quality-aware applications. Wireless link quality is naturally dynamic especially in mobile scenarios. Hence, accurate and expeditious packet delivery ratio estimation is a prior requirement for good performance in mobile, multi-hop and multi-rate Wireless Ad Hoc Networks. Zhou et al (2012) proposed a novel packet delivery ratio estimation method that improves accuracy and responsiveness of packet delivery ratio estimation. The proposed link quality estimation components are implemented in an IEEE 802.11b/g test-bed with experiments revealing that packet delivery ratio estimation improving by up to 50% in mobile scenarios without overhead. Measurement results show that the proposed method provides better route selection through increased end-to-end throughput when compared to
conventional procedures responding slowly to link dynamics. This improves decision making with regard to link quality. Nodes are capable of manipulating pheromone concentration without being dependent on ants (data packets) through link quality monitoring.

Hauspie et al (2001) suggested a link quality evaluation metric and a fast/reliable protocol to compute it and which proved through experiments that it could provide a good metric of link robustness without affecting network efficiency through “broadcast storms”. Node computation is light and handles topology well due to the algorithm being de-centralized.

Chin and Lowe (2006) outlined a simple Rate Opportunistic Ad-hoc on-demand distance vector Routing (ROAR) approach which helps AODV routing protocol strengthen routes through recruitment of neighbor nodes as support node on a least cost path during route construction. Working in tandem with a MAC it uses an opportunistic forwarding scheme that takes advantage of hop node diversity. ROAR was implemented in the NS-2 simulator over IEEE 802.11a physical layer. Simulation studies with different network topologies/realistic radio propagation model proved that ROAR increased AODV’s packet delivery ratio and end-to-end throughput by several orders of magnitude, specifically for hop count based routes. Hence, ROAR ensures an add-on allowing routing protocols to benefit from diversity without relying on physical layer approaches.

Yang and Huang (2008) proposed a new routing protocol which can provide QoS guarantee. In the route discovery phase, it finds paths meeting delay requirement with great link stability factor. In the route maintenance phase, it effectively keeps monitoring network topology changes through delay prediction and performs rerouting in time. Simulation results show that it can meet with the delay requirement while decreasing the routing cost.
Moh et al (2011) proposed a link quality aware routing protocol for MANETs resulting in robust delivery and high performance by finding out a reliable path with strong links. During route discovery, the strong links are effectively exploited by forwarding the RREQ packet with the highest link quality or Signal to Interference plus Noise Ratio (SINR) among the multiple RREQ packets received. Compared to the conventional protocols such as AODV, in which only the first-arrived RREQ is forwarded and the others are ignored, the proposed scheme may not have the minimum hop-count route but the one with more number of hops. However, the discovered route is a reliable path with high data rate because it consists of strong links, resulting in high performance as well as robust routing. According to the performance study, it is shown that packet delivery ratio is improved by up to 70% and per-route good-put is dramatically increased by a factor of up to 12. It is also shown that the acceptable value of the RREQ waiting time ($T_w$) is 1 msec in the simulated environment, which is enough to achieve fairly good performance.

Kim et al (2011) provided a comparative analysis of various routing strategies that affect the end-to-end performance in wireless mesh networks. First improve well-known link quality metrics and routing algorithms to enhance performance in wireless mesh environments. Then investigated the route optimality, i.e., whether the best end-to-end route with respect to a given link quality metric is established, and its impact on the network performance. Network topologies, number of concurrent flows, and interference types are varied in the proposed evaluation and found out that a non-optimal route is often established because of the routing protocol’s misbehavior, inaccurate link metric design, interflow interference, and their interplay. Through extensive simulation analysis, presented the insights on how to design wireless link metrics and routing algorithms to enhance the network capacity and provide reliable connectivity.
Routing in an ad hoc network is extremely challenging because of its dynamic nature, limited bandwidth and power energy. Somehow, Swarm Intelligence based techniques such as Ant Colony Optimization (ACO) algorithms have shown to be a good technique for developing routing algorithms for ad hoc networks. ACO based routing is an efficient routing scheme based on the behaviour of foraging ants. The collective behaviour of ants helps to find the shortest path from the nest to a food source, by deposition of a chemical substance called pheromone on the visited nodes. This mechanism from collective intelligence is applied to the ad hoc network by researchers. Gupta et al (2012) brought some characteristics as well as performance analysis of the proposed ACO based ad hoc routing protocols and compared them with the well-known ad hoc routing protocols. The results presented also help the researchers to understand the differences among various ACO based routing algorithms and to choose appropriate protocol for their research work. The proposed study showed how this approach has significantly improved the performance of the ad hoc networks.

Energy efficient routing is one of the most important design criterion for MANET since mobile nodes are battery powered with limited capacity and which cannot be recharged when ever needed. So, MANET routing is challenged by power and bandwidth constraints. When mobile nodes run out of power, the network gets partitioned and thus some sessions are disconnected. In order to solve this problem and to achieve efficient energy consumption, many solutions have been proposed. All those works are done as the extension of the already existing ad hoc routing protocols such as Reactive, Proactive and Hybrid Routing. Since table-driven protocols consume more energy compared to on-demand protocols, the proposals made modifications to existing reactive protocols. Mathews et al (2012) referenced most of the energy-aware protocols implemented as modifications of the basic routing protocols using energy-sensitive metrics. Link stability is also an
important challenge of MANET routing. Many routing algorithms have been proposed for providing QoS in terms of link stability. The proposed system concentrated on evaluating how these approaches and algorithms affect the energy consumption in the mobile devices and how stable routes are established in the network.

Significant research has been carried out in the recent years for generating systems exhibiting intelligence for realizing optimized routing in networks. Nair and Sooda (2011) proposed a grade based two level node selection methods along with Particle Swarm Optimization (PSO) technique. It assumes that the nodes are intelligent and there exists a knowledge base about the environment in their local memory. There are two levels for approaching the effective route selection process through grading. At the first level, grade based selection is applied and at the second level, the optimum path is explored using PSO. The simulation has been carried out on different topological structures and it is observed that a graded network produces a significant reduction in number of iteration to arrive at the optimal path selection.

MANETs are continuing to attract the attention for their potential use in several fields. Most of the work has been done in simulation, because a simulator can give a quick and inexpensive understanding of protocols and algorithms. However, experimentation in the real world is very important to verify the simulation results and to revise the models implemented in the simulator. Ikeda et al (2009) presented the implementation and analysis of the test-bed considering the Link Quality Window Size (LQWS) parameter for OLSR protocol. The proposed system investigated the effect of mobility in the throughput of a MANET. The mobile nodes move towards the destination at a regular speed. When the mobile nodes arrive at the corner, they stop for about three seconds. Through the proposed experiments, two cases are considered:
only one node is moving (mobile node) and two nodes (intermediate nodes) are moving at the same time. The performance is assessed on the proposed test-bed in terms of throughput, round trip time, jitter, and packet loss. From the experiments, it was found that throughput of TCP was improved by reducing LQWS.

Wireless Sensor Networks consisting of nodes with limited power are deployed to gather useful information from the field. In WSNs it is critical to collect the information in an efficient manner. It is applied in routing and difficult power supply area or areas that cannot be reached and some temporary situations, which do not need fixed network supporting and it can deploy quickly with strong anti-damage. In order to avoid the problem Fathima and Sindhanaiselvan (2013) proposed a new technique called Bio-Inspired mechanism for routing. ACO is one of the Bio-inspired mechanisms. ACO is a dynamic and reliable protocol. It provides energy-aware, data gathering routing structure in wireless sensor network. It can avoid network congestion and fast consumption of energy of individual node. Then it can prolong the life cycle of the whole network. ACO algorithm reduces the energy consumption. It optimizes the routing paths, providing an effective multi-path data transmission to obtain reliable communications in the case of node faults. The main goal is to maintain the maximum lifetime of network, during data transmission in an efficient manner. The proposed system defined the implementation of WSN and comparison of its performance with AODV routing protocol based on an ant algorithm done in terms of packet delivery ratio, throughput and energy level. Performance of the algorithm in comparison of AODV is much better.

Recently a great emphasis has been given on Autonomous Decentralized Networks (ADNs) wherein constituent nodes carry out specific tasks collectively. Their dynamic and constrained nature along with the
emerging need for offering QoS assurances drive the necessity for effective network control mechanisms. Antoniou et al (2009) designed a robust and self-adaptable congestion control mechanism which aims to be simple to implement at the individual node, and involve minimal information exchange, while maximizing network lifetime and providing QoS assurances. The proposed approach combats congestion by mimicking the collective behavior of bird flocks having global self properties achieved collectively without explicitly programming them into individual nodes. The main idea is to ‘guide’ packets (birds) to form flocks and flow towards the sink (global attractor), whilst trying to avoid congestion regions (obstacles). Unlike the bio-swarm approach of Couzin, which is formulated on a metrical space, this proposed approach is reformulated on to a topological space (graph of nodes), while repulsion/attraction forces manipulate the direction of motion of packets. The proposed approach provided sink direction discovery, congestion detection and traffic management in ADNs with emphasis on Wireless Sensor Networks (WSNs). Performance evaluations showed the effectiveness of self-adaptable mechanism in balancing the offered load and in providing graceful performance degradation under high load scenarios compared to typical conventional approaches.

Biradar et al (2010) proposed a mesh based multicast routing scheme that finds stable multicast path from source to receivers. The multicast mesh is constructed by using route request and route reply packets with the help of multicast routing information cache and link stability database maintained at every node. The stable paths are found based on selection of stable forwarding nodes that have high stability of link connectivity. The link stability is computed by using the parameters such as received power, distance between neighboring nodes and the link quality that is assessed using bit errors in a packet. The proposed scheme is simulated over a large number of MANET nodes with wide range of mobility and the performance is evaluated.
Performance of the proposed scheme is compared with two well-known mesh-based multicast routing protocols, i.e., On-Demand Multicast Routing Protocol (ODMRP) and Enhanced On-Demand Multicast Routing Protocol (EODMRP). It is observed that the proposed scheme produces better packet delivery ratio, reduced packet delay, and reduced overheads (such as control, memory, computation, and message overheads).

As mobile ad hoc network is burgeoning, different applications are developing with different service requirements. In particular, multimedia applications and other real-time applications, e.g., voice transmission, require very stringent and inflexible QoS. A great magnitude of attention has been paid against cost and energy consumption and mobility for non-QoS-aware routing protocols. While QoS-aware routing protocols put emphasis on QoS matrices and mobility individually, unrestricted mobility of nodes invalidates old paths, causing the packets of the flow to wait until the routing protocol is able to get information about the new paths. This degrades the performance of the network, reducing the throughput and increasing the delay and packet loss. Mamun-Or-Rashid and Hong (2007) mingled the idea of link stability and energy consumption to uncover better paths in terms of both stability and cost along with QoS support.

Dearlove et al. (2012) described the rationale for and design considerations behind how link metrics are included in OLSRv2, in order to allow routing by other than minimum hop count routes. OLSRv2 essentially first determines local link metrics from 1-hop neighbors; these being defined by a process outside OLSRv2, then distributes required link metric values in HELLO and TC messages, and then finally forms routes with minimum total link metric. Using a definition of route metric other than number of hops is a natural extension that is commonly used in link state protocols.
Tirkey et al (2012) compared the performance of AODV and MANET using Hybrid Swarm Intelligence protocols. By the simulation results Mobile Ad-hoc Network using Hybrid Swarm Intelligence gives better performance with lower delay and lower overhead.

Providing efficient networking services in MANETs is very challenging due to mobility and unpredictable radio channel: a significant number of packets can be corrupted and/or lost. To increase reliability, various measures have been proposed. A popular approach is to use multiple paths and transmit an identical copy of the packet on each path (i.e., path redundancy). A more efficient way is to use Network Coding on top of path redundancy and send different, encoded packets on each path. Network coding can improve throughput efficiency. However, it increases delays. If channel disruption is intermittent, it behooves to “turn on” path redundancy and/or Network Coding only when packet loss is severe. Oh et al (2009) compared via simulation the performance of multipath routing with and without Network Coding (and with/without dynamic adaptation) for various motion and packet loss scenarios in terms of reliability, efficiency, robustness, and scalability.

As mobile devices are getting more ubiquitous, the paradigm of wireless MANETs is gaining popularity. However, MANETs impose new challenges because of their self-organizing, mobile and error-prone nature. Mobility prediction can mitigate the problems emerging from node mobility. Farkas, et al (2006) proposed an approach called XCoPred to predict link quality variations based on pattern matching which can be exploited for mobility prediction. XCoPred doesn’t require the use of any external hardware or reference point. Each MANET node monitors the Signal to Noise Ratio (SNR) of its links to obtain a time series of SNR measurements. When a prediction is required, the node tries to detect patterns similar to the current situation in the history of the SNR values of its links by applying the
normalized cross-correlation function. The found matches are then used as the base of the prediction. Simulations have shown that fairly accurate predictions around 2 dB of absolute average prediction error can be achieved with XCoPred in case of appropriate parameter settings and scenarios showing clear node mobility patterns.

Nakaoka et al (2006) proposed a Link Quality-based Hybrid Routing (LQHR) protocol for Wireless Ad Hoc Networks. LQHR takes account of link quality such as SNR between adjacent nodes and the link utilization level of each node. In LQHR, each node maintains routing information produced by OLSR, which is a proactive routing protocol for ad hoc networks. When a source makes a communication request, it finds a route to the destination node on the basis of the link quality. The proposed LQHR implemented on an experimental network, where laptop PCs were arranged on the same floor of a building, and audio-video streams were transmitted along a route selected by LQHR. To evaluate, the effectiveness of LQHR in audio-video transmission application-level QoS of LQHR with that of the standard OLSR in the presence of traffic flow in the network is compared. As a result, it is found that the routes selected by LQHR can provide shorter transmission delays and lower loss ratios in the transmission of the audio-video streams than those selected by the standard OLSR.

Mobility causes frequent link failures in ad-hoc networks. This results in a severe degradation of performance especially in case of high mobility of nodes. This is because the routing protocols for ad-hoc networks are not equipped to handle high mobility. Ali et al (2007) presented a new link management algorithm to locally manage links. This new mechanism is based on signal strength measurements. Developed the heuristic mechanism provided by OLSR based on hello packets to include signal strength measurements. The mechanism in OLSR uses Hello packets received/lost to
decide to establish the link or not. The problem with this approach arises when there is high mobility in which case the time to break the link and use a new path becomes significant. To overcome this, proposed protocol uses signal strength to determine if the link-quality is improving or deteriorating. The combination of the two mechanisms makes the link management more robust and also helps in anticipating link breakages thereby greatly improving performance.

Wireless Ad Hoc Networks will be an important component in future communication systems. The performance of Wireless Ad Hoc Networks can be improved by link quality-aware applications. Wireless link quality is dynamic in nature, especially in mobile scenarios. Therefore, accurate and fast packet delivery ratio estimation is a prerequisite to good performance in mobile, multi-hop and multi-rate Wireless Ad Hoc Networks. Zhou et al (2012) proposed a novel packet delivery ratio estimation method that improves the accuracy and responsiveness of the packet delivery ratio estimation. The proposed link quality estimation components are implemented in an IEEE 802.11b/g test-bed. The experiment results showed that the accuracy of the packet delivery ratio estimation can improve up to 50% in mobile scenarios without introducing overhead. The proposed system also showed the end-to-end performance impact of this improved estimation, on route selection using different routing metrics and configurations. The measured results showed that the proposed packet delivery ratio method leads to better route selection in the form of increased end-to-end throughput compared to traditional methods, which respond slowly to the link dynamics.

2.4  SWARM INTELLIGENCE FOR ROUTING IN AD HOC NETWORKS

A number of algorithms apply the architecture of known SI routing algorithms for wired networks directly to ad hoc networks. This leads to
proactive algorithms, in which all nodes send ants to all possible destinations. A first example is the Accelerated Ants Routing algorithm by Matsuo et al (2001), which was derived from Ants. It contains small adaptations to this algorithm, such as the no-return rule (which simply states that ants cannot pick their previous hop as next hop, so that simple loops are avoided), and is shown in simulation to perform better than AntNet in MANETs. The ABC-Ad Hoc algorithm by Tatomir and Rothkrantz (2004) on the other hand is based both on ABC and AntNet. While it uses forward ants that update pheromone for the path to their source, as is done in ABC, it uses formulas of AntNet to calculate pheromone updates and to make probabilistic routing decisions. In a simulation with rather limited mobility, the ABC-AdHoc algorithm was shown to perform better than AntNet.

The AntNet algorithm by Dhillon et al (2007) is directly derived from AntNet with the addition of periodic beacon messages for neighbour discovery and for keeping the routing tables locally up-to-date. Simulation results show that, for increasing node mobility, performance degrades with respect to AODV and DSR, and the number of looping packets increases.

Other algorithms use elements of SI in a different way, which is however still proactive. Minar et al (1999) proposed to use a set of mobile agents that are quite independent of network nodes or data sessions: these agents are generated at network setup time, and they stay around indefinitely. They perform a continuous random walk through the network, keeping a history of the last N nodes they have visited. At each new node they arrive, paths are extracted from their history list in order to update routing information.

Camara and Loureiro (2001) proposed an algorithm that combines ants with geographic routing. In geographic routing, nodes are able to figure out their own geographic location, and data forwarding is based on the relative
location of the destination and the next hops. An important issue is how a
node can get to know the location of other nodes. In the proposed approach,
nodes use ants, sent to randomly chosen destinations, to inform other nodes
about their location.

The Mobile Ants-Based Routing Protocol (MABR) by Heissenbuttel
et al (2006) was designed for large scale ad hoc networks. This algorithm
divides the network area in rectangular zones, corresponding to geographical
areas. All nodes of a zone together make up a logical router. Long distance
routing is done between logical routers, with the aid of location information.
Ants are used at this level, to proactively update routing tables between logical
routers. In simulation, MABR compared favourably to Terminodes routing by

In AntHocGeo (Kudelski and Pacut (2009), the authors proposed a
modification of AntHocNet which implements the concept of geographical
localization of knowledge. The environment is partitioned into cells, such that
a routing path is first considered at the cell level rather than at the node level.
A mechanism is introduced to optimize the exchange of routing information
among the location-aware nodes while they move from one cell to the other.
The algorithm shows an improvement of performance with respect to
AntHocNet in simulation experiments and in tests using a network of
wirelessly connected mobile robots.

Baras and Mehta (2003) proposed a new algorithm, called
Probabilistic Emergent Routing Algorithm (PERA). This is a purely reactive
algorithm: forward ants are only sent out at the start of a communication
session, or when all existing routing information is out of date. They are
flooded through the network towards the destination. For every copy of the
forward ant that reaches the destination, a backward ant is sent to the source,
so that multiple paths are created at route setup time. In simulation studies,
PERA is found to have a performance that is comparable to AODV. On the downside, it must be noted that the algorithm is not very different from traditional reactive routing algorithms, such as AODV itself. This is on the one hand because, in the efforts to improve efficiency, a lot of the original SI routing mechanisms have been dropped, and on the other hand because some basic elements, such as a bottom up approach and the use of end-to-end path sampling, are generally useful in dynamic networks and have therefore been widely adopted in ad hoc network routing protocols such as AODV.

Ad Hoc Networking with Swarm Intelligence (ANSI) proposed by Rajagopalan and Shen (2005) is another algorithm that follows the same approach. It only uses ants at route setup time. A mechanism using forward and backward ants is applied, and like in Termite and ARA, data packets also deposit pheromone, in order to reinforce the paths they use. Data are routed deterministically over the best paths. ANSI evaluates paths based on the congestion rates of nodes along the path. ANSI was shown to perform better than AODV in simulation.

The BeeAdHoc by Farooq and Di (2008) algorithm, from the same authors of BeeHive, is based on the foraging bees’ metaphor, and adopts a different approach, based on the use of four different types of agents. Scout agents reactively broadcast using an increasing time-to-live heuristic in order to progressively enlarge the flooding area. When a good path is found, this is held by a different agent and made available at the nodes for data packets that are source-routed. In this way multiple paths can be used and no routing decision is taken at the intermediate nodes. BeeAdHoc is explicitly aimed at minimizing end-to-end delay and energy consumption. In a set of extensive simulation and real world experiments, BeeAdHoc has shown performance superior to AODV and DSR.
Emergent Ad Hoc Routing Algorithm (EARA) proposed uses ants to set up paths at the start of a communication session by Liu and Kaiser (2005). However, it does not stop there, and keeps on sending ants to the destination for as long as the session is active. New paths are detected using ants that do random walks through the network.

A very similar approach is followed in Ant Routing Algorithm for Mobile Ad Hoc Networks (ARAMA) proposed by Hussein et al (2005), that also makes use of pheromone evaporation, composite pheromone metrics, and so-called negative backward ants: when a forward ant incurs in a loop or expires its time-to-live, a backward ant is generated to decrease the pheromone along the path.

2.5 SUMMARY

In this chapter, various studies available in the literature related to the current research are reviewed. In the initial part of the chapter, ad hoc network in general is reviewed. The routing protocols used in MANET are reviewed with extra emphasis on AODV as it is used in this research. The various steps in the AODV are explored in detail. Similarly, routing based on the link quality of the nodes are reviewed. The works related to various optimization methods used to optimize the routing in wireless networks are discussed in detail.