International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org, editorijaiem@gmail.com
Volume 2, Issue 2, February 2013 ISSN 2319 - 4847

A Review on Routing Protocols in Wireless Mesh Networks

Er. Kulvir Singh[1], Er. Sunny Behal[2]

[1]Lecturer of Computer Engg. Govt.Polytechnic College G.T.B. Garh Moga, India

[2]Assistant Professor of Shaheed Bhagat Singh College of Engg. & Tech, Ferozepur, India

ABSTRACT

Wireless mesh networks have the potential to deliver Internet broadband access, wireless local area network coverage and network connectivity for stationary or mobile hosts at low costs both for network operators and customers. Routing is fundamental characteristics of wireless mesh network. The strengths and weakness of routing protocol are reflected directly in WMN's characteristics .This paper studies various types of routing protocols that are used in wireless mesh networks. This paper also provides mesh protocols functionality, characteristics and comparison analysis.

Keywords: Wireless Mesh Networks, Multi-hop , Proactive, Reactive.

1. INTRODUCTION

Wireless Mesh Networks (WMNs), consisting of wireless access networks interconnected by a wireless backbone, present an attractive alternative. Compared to optical networks, WMNs have low investment overhead and can be rapidly deployed. The wireless infrastructure is self-organizing, self-optimizing, and fault tolerant. It can extend IP connectivity to regions otherwise unreachable by any single access technology. Many companies, such as Nokia, Microsoft , Motorola and Intel are actively promoting wireless mesh networks as a full IP solution. Initial field tests have demonstrated WMN's [2] tremendous potential and market value. WMNs combine concepts from a diverse set of existing and emerging wireless technologies, including cellular technologies, ad hoc networks, and sensor networks.

In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating, in effect, an ad hoc network). This feature brings many advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage.

A typical WMN consists of mesh routers and mesh clients [1]. Mesh routers are fixed. They have a wireless infrastructure and work with the other networks to provide a multi-hop internet access service for mesh clients. On the other hand, mesh clients can connect to network over both mesh routers and other clients. In these networks, due to large number of nodes, working through some issues like security, scalability and manageability is required. Thus, new applications of WMNs make secrecy and security mechanisms are necessities.

Routing is an important factor to forward the data packet from source to destination node. To guarantee good performance, routing metrics must satisfy these general requirements are scalability, reliability, flexibility, throughput, load balancing, congestion control and efficiency. The routing metrics for mesh routing protocols are Hop Count, Blocking Metrics, Expected Transmission Count (ETX), The Expected transmission time (ETT), The Weighed Cumulative ETT (WCETT) .

2. CLASSIFICATION

Mesh routing protocols can be classified into three types which are as follows.

- Proactive Routing
- Reactive Routing
- Hybrid Routing

Proactive Routing

Proactive routing protocols are based on continuous information refreshing in routing tables. Information on any change in the network is sent at constant time periods. The main goal is to maintain up-to-date information in routing tables thus enabling the route selection in a most excellent manner. Some of the representative protocols based on table driven logic are OLSR and Destination sequenced distance vector (DSDV) [2]. Counting to infinity and maintaining up to date information may represent very difficult problems . One solution could be obtained through adding a special number to every node which will be incremented every time when a node environment change occurs, so a node with a higher number indicates that the node has refreshed information about changes. Based on this refreshed information, the route should be calculated again. The new route is stored in a local routing table. On the other hand, exchanges of the routing tables often have influence on network performances and increase time of convergence. With new information protocols, the route recalculation should be made. The proactive routing protocols [6] are Destination-Sequenced Distance-Vector Routing (DSDV), Cluster Head Gateway Switch Routing (CGSR) , Optimized Link State Routing Protocol (OLSR) and Scalable Routing using heat Protocols.

Reactive Routing

Reactive routing protocols calculate optimal route on demand. When a route is calculated, it is stored and used until the destination is available or the path's time is out. The mostly used reactive protocols are DSR and AODV [13]. In most cases these protocols have only information about next hops in the routing table. This information is time limited and will be automatically deleted if some of information is not used during the time. In this case, a new route calculation demands sending of Route Request (RREQ) packets to the neighborhoods. Having received this packet every neighbor sends the same packet to its neighbors. This logic is repeated until the RREQ packet is delivered to the destination node. After that, the destination node should reply by a Routing Reply (RREP) packet. Reactive protocol are also called on-demand protocol.

Hybrid Routing

In order to find most efficient routes, a hybrid protocol gives the possibility to combine some of the advantages of proactive and reactive routing protocols. As a reactive routing protocol, the proposed algorithm should find the optimal path on demand, based on up-to-date information. The reactive routing protocol and the procedure of sending a large number of RREQ and RREP packets are supposed to send information in discrete time intervals, after the routing request. On the contrary, the proposed algorithm should provide continuous updating of the routing information. Updated information should be available at every moment, thus decreasing the possibility of wrong routing decisions. On the other hand, the proposed solution should not send a complete routing table, but just changed parameters.

3. ROUTING IN WMNS

Wireless mesh networking and mobile ad hoc networking use the same key concept—communication between nodes over multiple wireless hops on a meshed network graph. Since WMNs [1] share common features with wireless ad hoc networks, the routing protocols developed for MANETs can be applied to WMNs. Wireless Mesh Networks are generally considered as the type of mobile ad-hoc networks. However there are some differences between them. Firstly in wireless mesh networks all most all the traffic starts from gateways and ends ups also on gateway. Secondly in wireless mesh networks, nodes are clearly separated from each other either they are in the form of stagnant nodes or mobile nodes. Additionally WMNs are new technological networks which are similar to MANETs. One of the applications of WMNs is that, it provides connection to an infrastructure node. It plays vital role for providing broadband internet access. The other successful production of WMNs is Wireless local area network. Routing is basic attribute of WMNs. The protocols have the clear effect on the behavior of WMNs. Therefore selection of suitable routing protocol increases the efficiency of network.

4. PROACTIVE ROUTING PROTOCOLS

4.1 Destination Sequenced Distance Vector

The destination sequenced distance vector (DSDV) [2] routing protocol is a proactive routing protocol which is a modification of conventional Bellman-Ford routing algorithm. This protocol adds a new attribute, sequence number, to each route table entry at each node .

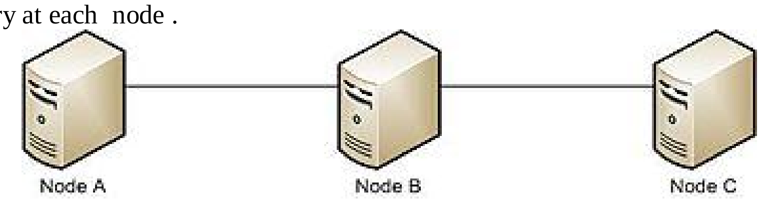

Fig .1 DSDV Routing Protocol in Network

In this algorithm each node maintains a routing table that contains the shortest path to every possible destination in the network and number of hops to the destination as shown in Fig.1.Each node in the network maintains routing table for

the transmission of the packets and also for the connectivity to different stations in the network. These stations list for all the available destinations, and the number of hops required to reach each destination in the routing table.
Routing table is maintained at each node as shown in Table 1. The routing entry is tagged with a sequence number which is originated by the destination station. In order to maintain the consistency, each station transmits and updates its routing table its routing table periodically. The packets being broadcasted between stations indicate which stations are accessible and how many hops are required to reach that particular station .The data broadcast by each node will contain its new sequence number and the following information for each new route:

- The destination address
- The number of hops required to reach the destination and
- The new sequence number, originally stamped by the destination

The routing table updates can be sent in two ways:- a "full dump" or an incremental update. A full dump sends the full routing table to the neighbors and could span many packets whereas in an incremental update only those entries from the routing table are sent that has a metric change since the last update and it must fit in a packet. If there is space in the incremental update packet then those entries may be included whose sequence number has changed.

Table 1: Routing Table at Node 1

Destination	**Next Hop**	**No. of Hops**	**Seq. No.**
A	A	0	A36
B	B	1	B36
C	B	2	C28

4.2 Clusterhead Gateway Switched Routing

Clusterhead Gateway Switch Routing protocol [4] is a multichannel operation capable protocol. It enables code separation among clusters. The clusters are formed by cluster head election procedure, which is quite intensive process. On that reason the protocol uses so called Least Cluster Change (LCC) algorithm for that election. By using LCC can cluster heads only changed when two cluster heads come into contact with each other or when a node moves out of contact of all other cluster heads.CGSR is not an autonomous protocol. It uses DSDV as the underlying routing scheme. The DSDV approach is modified to use a hierarchical cluster head-to-gateway routing. A packet sent by a node is first routed to its cluster head, and then the packet is routed from the cluster head to a gateway to another cluster head, until the destination node's cluster head is reached. That destination cluster head then transmits the packet to the destination node.

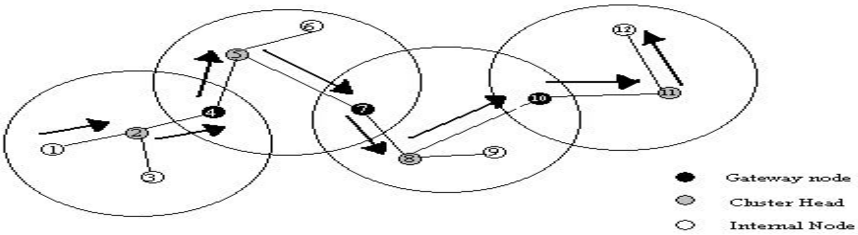

Fig. 2. Routing in CGSR form node 1 to 12

As shown in Fig. 2, when sending a packet, the source (node 1) transmits the packet to its clusterhead (node 2). From the clusterhead node 2, the packet is sent to the gateway node (node 4) that connecting to this clusterhead (node 2) and the next clusterhead (node 5).From the clusterhead node 5, the packet is sent to the gateway node (node 7) that connecting to this clusterhead (node 5) and next clusterhead (node 8) along the route to the destination (node 12). The gateway node (node 10) sends the packet to the next clusterhead (node 11), i.e. the destination cluster-head. The destination clusterhead (node 11) then transmits the packet to the destination (node 12). A Wireless Mesh Network is divided into multiple clusters for load control. A cluster head estimates traffic load in its cluster. As the estimated load gets higher, the cluster head increases the routing metrics of the routes passing through the cluster. Based on the routing metrics, user traffic takes an alternative route to avoid overloaded areas, and as a result, the WMN achieves global load balancing. The CGSR effectively balances the traffic load and outperforms the routing algorithm using the expected transmission time (ETT) as a routing metric.

4.3 Optimized Link State Routing

Optimized Link State Routing (OLSR) [13] is a topology based, neighbor selection protocol, in which each node only maintains a subset of network topology information. OLSR is a proactive protocol, because it exchanges the topology information with other nodes regularly to maintain information required for routing.

In the OLSR protocol, each node uses this flooding technique to distribute the link-state of its own MPR set. This is done periodically. The update period is in its minimum when there is detected a change and when the network is in its stabile state there is a updates only between refresh intervals. Each node uses the attained topology information to construct its routing tables. Each node broadcasts its link state information to all other nodes in the network.

For the neighbor sensing purposes the OLSR uses HELLO-messages, because each node should detect the neighbor interfaces with which it has a direct and symmetric link. OLSR supposes bi-directional links and so the connectivity must be checked in both directions. HELLO-messages are broadcast to all one-hop neighbors, but are not relayed to further nodes.. OLSR is well suited for networks, where traffic is random and sporadic between several nodes rather than being almost exclusively between a small specified set of nodes. The major advantage of OLSR over other Proactive Protocols is that it broadcasts its link State information rather than routing tables.

4.4 Scalable Routing using HEAT Protocol

The HEAT algorithm is a fully distributed, proactive any cast routing algorithm. It is inspired by the properties of temperature fields .HEAT has two unique features [8]. First, the routing is decided based on length and robustness of the available path. Second, the field construction and maintenance mechanism of HEAT scales to the number of nodes and the number of gateways, as it only requires communication among neighboring nodes. HEAT protocol assigns a temperature value to every node in the mesh network. New nodes are assigned a value of zero and gateway nodes are assigned a well-defined maximum value. This protocol determines the temperature of node based on

--Distances to the available gateways

--Robustness of the paths towards these gateways

That is, a path providing multiple alternative delivery opportunities along its way is preferred to a path over which packets cannot naturally be re-routed to an alternative path to one of the gateways. The Performance of the HEAT protocol [8] is better in wireless mesh networks in terms of packet delivery ratio than the OLSR and AODV.

5. REACTIVE ROUTING PROTOCOLS

5.1 Dynamic Source Routing

The Dynamic Source Routing Protocol [20] is a source-routed on-demand routing protocol. The two major phases of the protocol are: route discovery and route maintenance. When the source node wants to send a packet to a destination, it looks up its route cache to determine if it already contains a route to the destination. If it finds that an unexpired route to the destination exists, then it uses this route to send the packet. But if the node does not have such a route, then it initiates the route discovery process by broadcasting a route request packet. The route request packet contains the address of the source and the destination, and a unique identification number. Each intermediate node checks whether it knows of a route to the destination. If it does not, it appends its address to the route record of the packet and forwards the packet to its neighbors. To limit the number of route requests propagated, a node processes the route request packet only if it has not already seen the packet and it's address is not present in the route record of the packet.

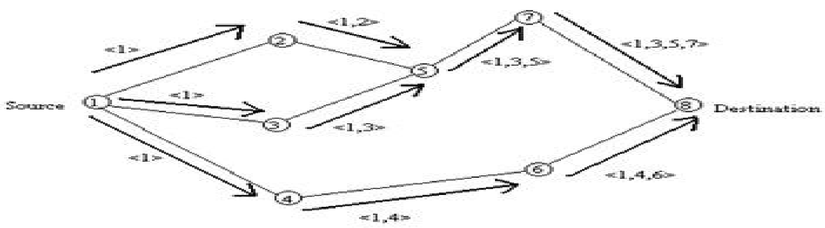

Fig. 3(a). Building Record Route during Route Discovery

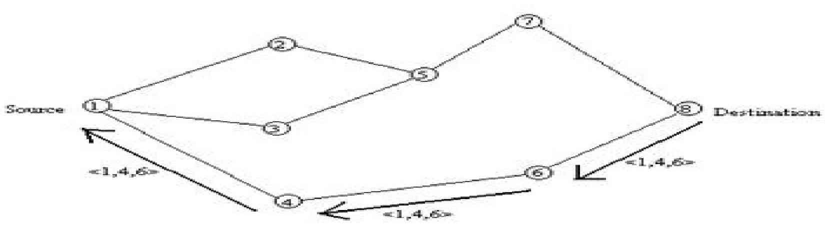

Fig. 3(b). Propogation of Route Reply with the Route Record

A route reply is generated when either the destination or an intermediate node with current information about the destination receives the route request packet. A route request packet reaching such a node already contains, in its route record, the sequence of hops taken from the source to this node.

As the route request packet propagates through the network, the route record is formed as shown in figure 3a. If the route reply is generated by the destination then it places the route record from route request packet into the route reply packet. On the other hand, if the node generating the route reply is an intermediate node then it appends its cached route to destination to the route record of route request packet and puts that into the route reply packet Figure 3b shows the route reply packet being sent by the destination itself. To send the route reply packet, the responding node must have a route to the source.

5.2 Ad hoc On Demand Distance Vector Routing

Ad hoc On-demand Distance Vector Routing (AODV) [19] is an improvement on the DSDV algorithm . AODV minimizes the number of broadcasts by creating routes on-demand as opposed to DSDV that maintains the list of all the routes.

To find a path to the destination, the source broadcasts a route request packet. The neighbors in turn broadcast the packet to their neighbors till it reaches an intermediate node that has a recent route information about the destination or till it reaches the destination (Figure 4a). A node discards a route request packet that it has already seen. The route request packet uses sequence numbers to ensure that the routes are loop free and to make sure that if the intermediate nodes reply to route requests, they reply with the latest information only.

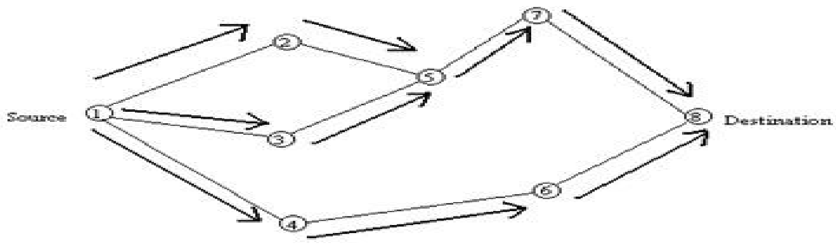

Fig. 4(a). Propogation of Route Request (RREQ) Packet

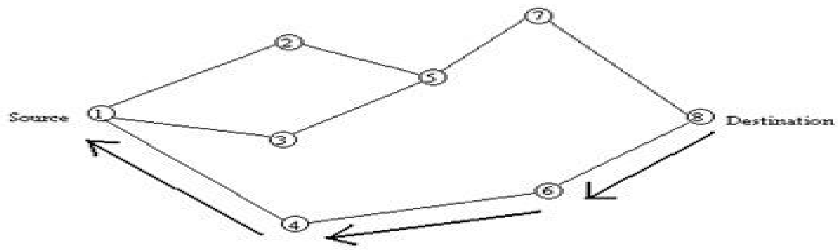

Fig. 4(b). Path taken by the Route Reply (RREP) Packet

When a node forwards a route request packet to its neighbors, it also records in its tables the node from which the first copy of the request came. This information is used to construct the reverse path for the route reply packet. ADOV uses only symmetric links because the route reply packet follows the reverse path of route request packet. As the route reply packet traverses back to the source (Figure 4b), the nodes along the path enter the forward route into their tables. Hence the AODV finds route which is fastest and shortest.

If the source moves then it can reinitiate route discovery to the destination. If one of the intermediate nodes move then the moved nodes neighbor realizes the link failure and sends a link failure notification to its upstream neighbors and so on till it reaches the source upon which the source can reinitiate route discovery if needed.

5.3 Link quality source routing

Link Quality Source Routing (LQSR) [4] is a reactive protocol for wireless mesh networks developed by Microsoft Research Group [11]. It is based on DSR algorithm by improving link quality metrics and other related metrics. The metrics are hop count, round trip latency (RTT), packet pair latency and Expected Transmission Count (ETX).To improve the link quality, and LQSR uses link cache instead of route cache.

In LQSR, When a node wants to send a data then that node looks at the link cache for destination route. If the route exists then send the data. Otherwise it broadcast the Route Request Packet to its neighbors until it reaches the destination. When a node receives a route request (RREQ) packet [3], it will add link quality metric for the link over which packet had arrived. When a Source node receives route reply (RREP) packet, it includes link quality information and node information LQSR sends Hello message to its neighbors for link state information which is used to measure the link quality at each node for the link on which this message was received. All these messages are based on piggybacked approach.

5.4 TORA

The TORA protocol is a highly adaptive loop-free distributed routing algorithm based on the link reversal algorithm [8]. This protocol is designed to discover routes on demand and it provides multiple routes for any desired source-destination pair. TORA protocol minimizes communication overhead by localizing algorithmic reaction to topological changes when possible. The TORA protocol is based on the concept of the localization of control messages to a small set of nodes near the occurrence of a topological change [11]. This can be done by maintaining routing information about adjacent (one-hop) nodes. This protocol maintains a destination-oriented directed acyclic graph (*DAG*) for each possible destination.

TORA protocol uses the notation of height to find the direction of each link. The height of the source node is defined as the largest value and the height of the destination node is the smallest value . All nodes in the network make use of height when any node in the network attempts to communicate with another node. The logical links are considered to be directed from nodes with higher height towards nodes with lower height . *TORA* functionality based on three basic phases, that is, route creation, route maintenance, and route erasure. During the route creation and maintenance phases, nodes use a height metric to establish a *DAG* rooted at destination (i.e. the destination is the only node with no downstream links) . Route maintenance will be used to reestablish a *DAG* due to topology changing (during the times of mobility). *TORA* also employs three control packets are used by each function, that is, Query (*QRY*), Update (*UPD*), and Clear (*CLR*).

6. HYBRID ROUTING PROTOCOLS

6.1 Hazy-Sighted Link State Routing Algorithm (HSLS)

In HSLS,[2] two Proactive algorithms are adapted. The algorithms are Near-Sighted Link-State Routing and Discretized Link-State Routing. Near-Sighted Link-State Routing algorithm is used to find the number of node-hops that routing information may be transmitted. Discretized Link-State Routing is used to find the limits the times that the routing information may be transmitted. The reactive routing is needed, if any failure attempt to use an adjacent link causes the next timer to expire, retrieve the information to find an alternate route.

The main aim is here, to measure the global network wastage. It includes transmitting route updates inefficient transmission routes. It means "The total overhead is defined as the amount of bandwidth used in excess of the minimum amount of bandwidth required to forward packets over the shortest distance by assuming that the nodes had instantaneous full-topology information."

In HSLS, mathematical optimization is used to find the times to transmit link state updates, and also the breadth of nodes that the link state updates. A local routing cache update is needed whenever a connection is lost. This is the reactive part of the algorithm. HSLS provides good scalability properties and establishes pretty good routes in real time. The routing information and the data transfer are decentralized, so it provides good reliability and performance.

7. COMPARISON OF ROUTING PROTOCOL

Table 2 gives comparison of various routing protocols for wireless mesh networks. Routing Metrics are used for comparison,

Table 2: Comparison of Routing Protocols for Wireless Mesh Networks

Routing Protocols	Classification	Routing Metrics	Mobility	Loop Fee	Scalability	Reliability	Load Balancing	Congestion Control	Throughput	Hello msg	Multicasting
DSDV	Proactive	Shortest Path	Yes	Yes	No	Yes	No	No	Decrease with mobility	No	No
CGSR	Proactive	Shortest Path	Yes	Yes	Yes	Yes	Yes	Yes	Decrease with mobility	No	No
OLSR	Proactive	Shortest Path	Yes	Yes	No	Yes	No	No	Better compared to DSDV	Yes	No
Scalable Routing	Proactive	Hop Count	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
DSR	Reactive	Shortest path	Yes	Yes	No	Yes	No	Yes	Decrease with mobility	No	No
ADOV	Reactive	Fast & Shortest Path	Yes	Yes	No	Yes	No	Yes	Decrease with mobility	Yes	Yes
LQSR	Reactive	Hop count , RTT, ETX	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
TORA	Reactive	Hop Count	Yes	Yes	Yes	Yes	No	No	Better compared to DSDV	No	Yes
HSLS	Hybrid	Hop count , RTT, ETX	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

how to acquire and maintain routing information and whether they are loop free or not .And also specifies which Protocol provides greater scalability, reliability, load balancing , congestion control and throughput.

8. CONCLUSION

Wireless mesh networks are becoming increasingly popular as they have significant advantages over competing technologies. Routing Protocol is an important component of communication in Wireless Mesh Networks. In this paper, we have presented the classification of mesh routing protocols . We have presented theoretical details of Proactive routing protocols like DSDV, CGSR, OLSR and Scalable routing. We have also presented theoretical details of Reactive routing protocols like DSR, ADOV, LQSR and TORA and hybrid protocol such as HSLS. We have been discussed the various routing protocols of wireless mesh networks and compared with the properties So we can select an effective protocol, depending up on the network and other conditions.

REFERENCES

[1] Mesh Networking Forum, Building the business case for implementation of wireless mesh networks, Mesh Networking Forum 2004, San Francisco, CA, October 2012.

[2] Pathak , P. H.; Dutta , R. (2011). "A Survey of Network Design Problems and Joint Design Approaches in Wireless Mesh Networks". *IEEE Communications Surveys & Tutorials* **13** (3): 396–428.

[3] International Journal of Research and Reviews in Wireless Sensor Networks (IJRRWSN) Vol. 1, No. 3, September 2011, ISSN: 2047-0037 A Survey: Routing Protocols for Wireless Mesh Networks

[4] K.P. Vijayakumar , P . Ganeshkumar and M. Anandaraj ," Review on Routing Algorithms in Wireless Mesh Networks. International Journal of Computer Science and Telecommunications [Volume 3, Issue 5, May 2012] 87

[5] J. Liu, S. Singh, ATCP: TCP for mobile ad hoc networks,IEEE Journals on Selected Areas in Communications 19 (2012)

[6] Ramjee R, Varadhan K, Salgarelli L, Thuel SR , Wang S-Y, La Porta T (2011) Hawaii: a domain based approach for supporting mobility in wide-area wireless networks. IEEE/ACM Trans N6tw10(3):396–410

[7] Servetto SD , Barrenechea G (2012) Constrained random walks on random graphs: routing algorithms for large scale wireless sensor networks. In: Proceedings of the 1st ACM

[8] Draves R, Padhye J, Zill B (2012, August) Comparison of routing metrics for static multi-hop wireless networks. In: echnologies, Architectures, and Protocols for Computer Communications

[9] www.wikipedia.org

[10] A. Acharya , A . Misra , S. Bansal , High-performance architectures for IP-based multihop 802.11 networks, IEEE Wireless Communications 10 (5) (2011) ..

[11] J. Pan , L. Cai , T. Hou , Y. Shi, and S. Shen:Topology control for wireless sensor networks, Proceedings of the Nineth ACM MobiCom,(2012).

[12] Rayner K (2011, October–November) Mesh wireless networking. Communications Engineer 1(5)

[13] Sunil Kumar, Jyotsna Sengupta , " AODV and OLSR Routing protocols for Wireless Mesh Network an Ad-hoc Networks" IEEE ICCCT Sept, 2011 at MNNIT Allahabad.

[14] A . Adya , P. Bahl , J. Padhye , A . Wolman , L. Zhou , A multi-radio unification protocol for IEEE 802.11 wireless networks, in: International Conferences on Broadband Networks (BroadNets), 2012

[15] O.B . Akan , I.F . Akyildiz , ARC for real-time traffic: ARC: the analytical rate control scheme for real-time traffic in wireless networks, IEEE/ACM Transactions on Networking 12 (4) (2012) .

[16] Y. Drabu and H. Peyravi, “Planning with Joint Clustering in Multi-hop Wireless Mesh and Sensor Networks”, The Tenth International Conference on Networks, 2011,

[17] K. Sanzgiri, B. Dahill , B.N. Levine , C. Shields, E.M. Belding-Royer, A secure protocol for ad hoc networks, in: IEEE International Conference on Network Protocols (ICNP), 2012, pp. 78–87

[18] Y. Sun, E. Belding-Royer, and C. Perkins, “Internet connectivity for ad hoc mobile networks,” in in International Journal of Wireless Information Networks, special issue on Mobile Ad hoc Networks, 2010

[19] C. Perkins, E. Belding - Royer, and S. Das, “ Ad hoc On-Demand Distance Vector (AODV) Routing ,” RFC 3561 (Experimental), Jul. 2010. [Online]. Available: http://www.ietf.org/rfc/rfc3561.txt

[20] D. B. Johnson, D. A. Maltz, and J. Broch. DSR: The dynamic source routing protocol for multihop wireless ad hoc networks. In *Ad Hoc Networking*, 2011