

Routing Techniques in Mobile Ad-Hoc Networks (MANETs): An Analytical Review and Concerned Challenges

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Abstract

Mobile Ad-Hoc Networks (MANETs) are wireless, infrastructure less, self-configuring, dynamic topology, lower range, lower power network where all the nodes act as router as well as hosts. MANETs having dynamic topology are themselves responsible for finding the route to other nodes for communication. From the past few years mobile Ad-Hoc networks have gained attention of many researchers because of some issues present in it that need serious considerations. Routing is one of the main issues of concern in this paper, we present some of existing routing protocols and challenges faced by those routing protocols. Comparative analysis of various flat routing protocols and hierarchical routing protocols along with their advantages and disadvantages is depicted.

Keywords

MANETs, Routing Protocol, Security in MANETs

I. Introduction

With the rapidly evolving communication technologies there requires the need for ad hoc networks over wired networks. A MANET is an infrastructure less and self configuring network which communicates without prior set up of the network. Its some of the application areas includes crisis management, telemedicine, education via internet, mine operations, military operations, civilian application, sensor networks, image processing, monitoring aquatic environment, scientific applications, intelligent transportation system.

In spite of having several advantageous features, it also possesses some of the challenging issues [1] that are required to be taken into account in order to increase MANET survivability. Those issues include the following:

A. Routing Efficiency

Due to mobility in the network, the protocol used must provide with such efficiency.

B. Security Services

As mobile nodes are more susceptible to vulnerabilities so considering security parameters makes prime issue to be concerned. Some of the problems that commonly arise are hidden terminal problem, packet loss etc.

C. Quality of Service (QoS)

Providing QoS in rapidly changing environment is a big issue to achieve. In order to achieve quality of service in such an environment, it is required that protocol must fulfil the basic features such as lower delay while transmission, higher bandwidth for efficient transmission.

D. Power Management

Better power management is an efficient mean to reduce power consumption at various nodes thus prolonging the battery life of mobile nodes.

E. Bandwidth Management

Bandwidth available for transmitting data over the network is quite restricted over a particular range only. So it is required to manage the available bandwidth from selfish nodal attack that unnecessarily consumes the available bandwidth.

F. Mobility Management

In ad hoc network nodes can join or leave the network unrestrictedly. So it is required to manage storage, retrieval and maintenance of position of mobile nodes efficiently.

II. Routing in MANETs

Whenever large number of population wish to communicate then there arises the need for efficient routing procedures so that there do not occur any wastage of available resources such as bandwidth, battery requirement etc. Also in MANETs scalability is the main issue to be concerned as if the nodes are stationary then large population can be handled efficiently while when nodes are mobile routing procedures for handling mobility issues also requires great concern. There are numerous protocols available for mobile ad hoc networks. These routing protocols can be categorized as shown in fig. 1.

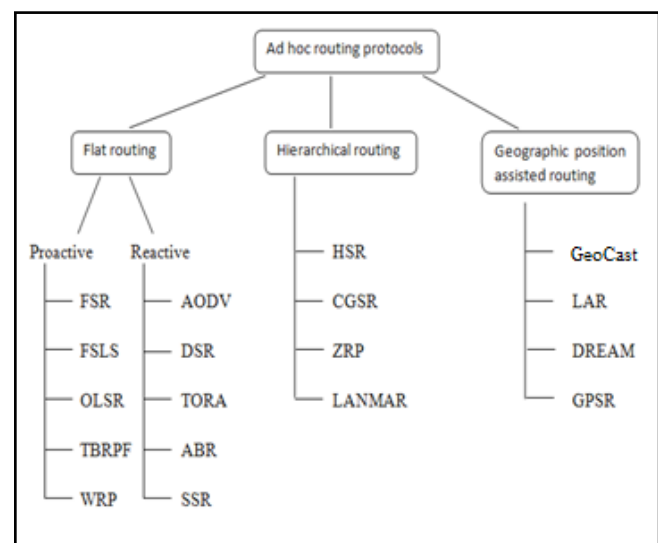


Fig. 1: Classification of Ad-Hoc Routing Protocol

A. Flat Routing

Flat routing approaches use a flat addressing scheme. Each node participating in routing plays an equal role. This requirement is quite realistic today since such types of devices are inexpensive and provide reasonable precision. Protocols in this category fall in the two categories- proactive and reactive.

1. Proactive Routing Protocol

Proactive protocols maintain the routing information of all the nodes present in the network irrespective of their routing requests. The routing information is usually kept in routing tables. The routes to all the nodes are determined at the start up and is maintained periodically using a route update process by transmitting control

messages to all the nodes.

(i). Wireless Routing Protocol

Wireless Routing Protocol (WRP) is a protocol [2] that guarantees loop freedom. Each node in the network maintains four tables:

- Distance table
- Link cost table
- Routing table

Message Retransmission List (MRL) table

MRL table contains the sequence number of the update message, a retransmission counter, an acknowledgement-required flag vector with one entry per neighbour and list of updates. WRP avoids loop by enforcing consistent check for predecessor information provided by all its neighbours thus providing faster route recovery whenever link failure occurs.

(ii). Fisheye State Routing

Fisheye State Routing (FSR) protocol [3] is simple and efficient LS type routing protocol. In FSR, updation is done only for neighbour nodes with higher frequency rate rather than flooding over the network for those nodes which lie outside the fisheye scope. This leads to the improved scalability in FSR. However, scalability may lead to reduced accuracy because as the mobility in the network increases the routes to destination become lesser accurate.

(iii). Open Link State Routing Protocol

Open Link State Routing Protocol (OLSR) [4,12] is a point-to-point routing protocol based on link state routing in which each node periodically exchanges the topological information with other nodes in the network by exchanging link-state messages. The novelty of OLSR protocol is that it uses Multipoint Relay (MPR) [5] to reduce the number of broadcast packets retransmission thus leading to efficient flooding of control messages in the network. For this each node in the network selects its neighbouring nodes to retransmit its packets. The set of nodes is called multipoint relay of that node. By flooding a message to its MPRs, it ensures that the message that is being retransmitted is received by all its two-hop neighbours only as shown in fig. 2. The node which is not part of relays can only read and process each packet but cannot perform retransmission.

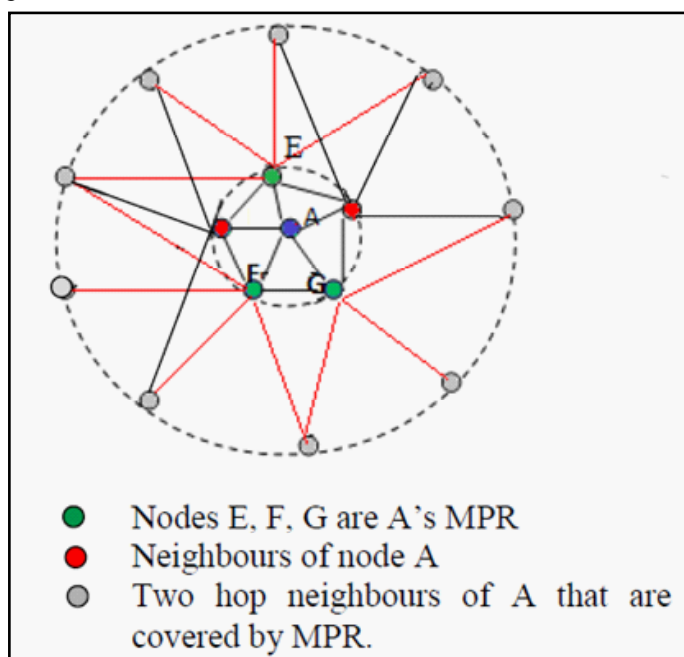


Fig. 2: OLSR- Multipoint Relays

(iv). Topology Broadcast Based on Reverse Path Forwarding

Topology Broadcast Based on Reverse Path Forwarding (TBRPF) [6] is hop-by-hop routing protocol based on LS protocol. TBRPF performs two tasks: the neighbour discovery module and the routing module. Neighbour discovery is performed by periodically broadcasting "differential" HELLO messages that report for the changes (lost or gain) of neighbours. This routing strategy uses modified Dijkstras algorithm to calculate a source tree, which provides a path to all reachable destinations. Instead of flooding over the entire network, link-state updates in reverse direction on the spanning tree formed from all minimum path nodes to the source of the update. The differential updates are issued more frequently thus leading to faster changes, less routing overhead [7].

2. Reactive Routing Protocol

On-demand routing protocols were designed to reduce the overheads in proactive protocols by sending routing packets only when the communication is awaiting [8].

So, it establishes the route dynamically when it is required. It invokes the route discovery procedure for transmission of information from source to destination. Unlike proactive protocols, the route remains valid as long till the destination is reached or the discovered route is no longer needed.

(i). Dynamic Source Routing protocol

Dynamic Source Routing protocol (DSR) [9] is based on-demand based routing rather than table based. All the nodes maintain the route cache containing source routes, that is, query packet copies the Ids of the entire intermediate node that it has traversed on the way.

During route discovery procedure, when source node sends packet to destination, it first consults the route cache to determine whether there is any pre-established path present to destination. If it is available then it uses that route for transmission.

Otherwise, it initiates route discovery by broadcasting route request packet. The route request contains address of destination, source node address and a unique identification number. When it reaches the destination, it then retrieves the entire path from query packet and responds to the source node as a route reply. DSR enables nodes to keep multiple routes to a destination. The path included in the packet header makes the detection of loops very easy.

(ii). Ad-Hoc on-Demand Distance Vector Routing Protocol

Ad Hoc On-Demand Distance Vector Routing Protocol (AODV) [10] is a pure on-demand route acquisition system as the nodes that are not part of the network do not maintain routing information table. In AODV, the communication from source to destination is initiated by sending path discovery process. It broadcast a route request (RREQ) packet to its neighbour nodes. Each node maintains routing table which stores source and destination address and next hop IP address as well as its sequence number (Broadcast ID).

So if again RREQ is detected then that packet is discarded. When the destination is reached, it generates route reply (RREP) packet and sends it back to the source node using Table as shown in fig. 3.

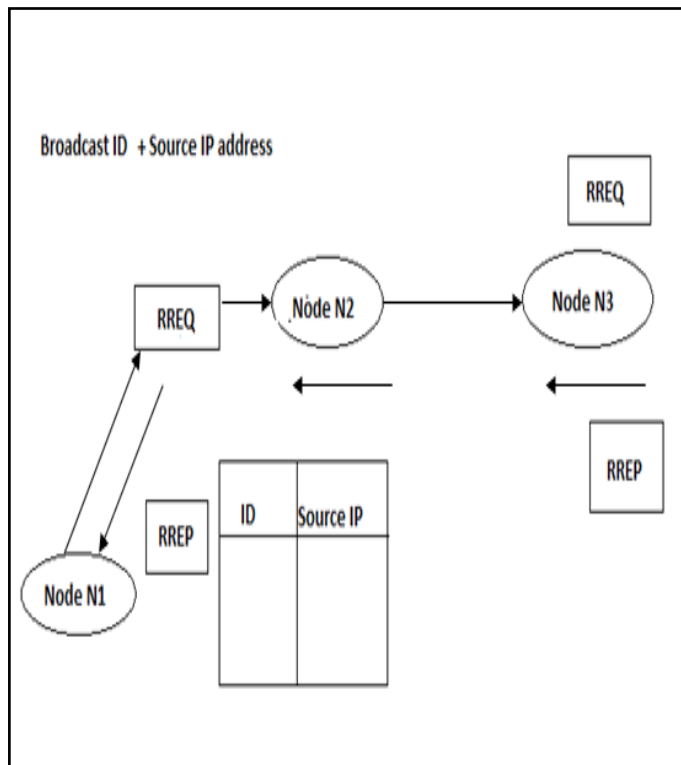


Fig. 3: Mechanism of AODV Protocol

B. Hierarchical Routing Protocols

When wireless size increases, flat routing schemes become infeasible because of overhead involved. The solution to this is to use scalable and efficient hierarchical routing protocol. Wireless hierarchical routing is based on the idea of organizing nodes in groups and then assigning nodes different functionalities inside and outside a group.

(i). Cluster head-Gateway Switch Routing

Cluster head-Gateway Switch Routing (CGSR) is type of cluster-based hierarchical routing. To partition the whole network into clusters, a stable clustering algorithm, Least Cluster head Change (LCC), is used.

A gateway is used to connect two or more clusters. Data packets are routed through paths having a format of the form “Cluster head–Gateway Cluster head–Gateway” between source and destination pairs. CGSR is a distance vector routing algorithm. In this two tables are used, a cluster member table and a DV routing table. The cluster member table keep the record of cluster head for each node. The routing table contains one entry for each cluster recording the path to its cluster head without regarding how many members it has.

For routing a data packet, the node first checks for the cluster head of the destination node from the cluster member table. Then it checks its routing table to find the next hop to which the packet is to be send and routes the packet toward the destination cluster head. The destination cluster head will finally route the packet to the destination node, which is its member and can reach directly as shown in fig. 4. CGSR greatly reduce the routing table size as only one entry is needed for all nodes in the same cluster.

(ii). Hierarchical State Routing

Hierarchical State Routing (HSR) [8,11] is a multilevel clustering-based on LS routing protocol. It recursively uses clustering scheme to maintain a logical hierarchical topology. Nodes which are present at the same level are grouped into one cluster. The

electd cluster heads present at the lower level become members of the next higher level. The goal of clustering is to reduce routing overhead (i.e., routing table storage, processing, and transmission) at each level.

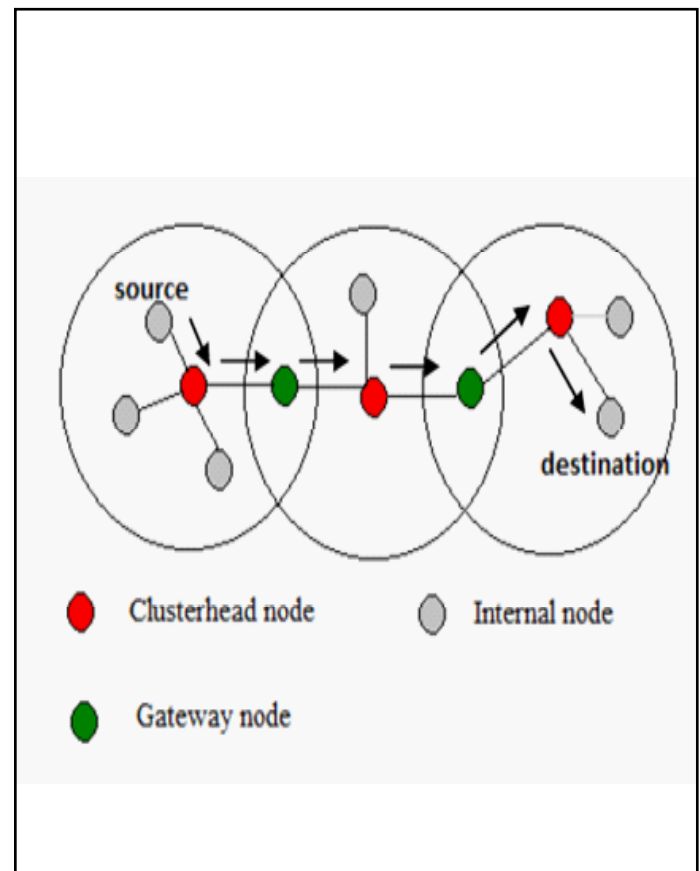


Fig. 4: CGSR Routing Depicting Path Traversal from Source to Destination

(iii). Zone Routing Protocol

Zone Routing Protocol (ZRP) [8] is a hybrid routing protocol that combines both proactive and on-demand routing strategies. The nodes which lie within the same zone use proactive routing protocols for maintaining routing information. And the nodes that lie outside its zonal area, their routing information is not stored permanently. The ZRP protocol consists of three components.

- Proactive Intrazone Routing Protocol (IARP) is used for maintaining the routing information within the zone. IARP can be any LS routing or distance vector routing depending on the implementation.
- Reactive Interzone Routing Protocol (IERP) is used for nodes lying outside the zone. IERP uses the Route Query (RREQ)/Route Reply (RREP) packets to discover a route.
- Bordercast Resolution Protocol (BRP) is used when the intended destination is not known (i.e., not in its IARP routing table), then the node must lie outside its zone. Then RREQ packet is broadcast to the nodes present on the border of the zone. Such a RREQ broadcast is called Bordercast Resolution Protocol (BRP).

Table 1, summarizes the brief comparative analysis of several flat routing and hierarchical routing protocols studied so far depicting comparison of their routing strategy used for the communication, their advantages and disadvantages along with their storage [8] and communication complexity.

Table 1: Comparative Analysis of Routing Protocols

Protocols	Routing Strategy	Advantage	Disadvantage	Storage complexity	Communication complexity
FSR	Proactive routing strategy	Loop free, controlled frequency of updates	High memory overhead	$O(N)$	$O(N)$
OLSR	Proactive	Reduce control overhead using MPR	Requirement of 2-hop neighbour knowledge	$O(N)$	$O(N)$
TBRPF	Proactive	Broadcast topology updates over a spanning tree	High memory overhead	$O(N)$	$O(N)$
AODV	On-demand	Lower set-up delay, reduced overhead	Require periodic updates, unnecessary band width consumption	$O(e)$	$O(2N)$
DSR	On-demand	Route establishment when required, loop free, load reduction	Scalability problems due to source routing and flooding	$O(e)$	$O(2N)$
HSR	Proactive, link state	Reduced routing overhead, loop free	Process of leader election in every cluster is difficult to manage	$O(M \cdot H)$	$O(M \cdot H)$
CGSR	Proactive, distance vector	Reduced broadcast packet size, Loop free	No multicast capability	$O(N/M)$	$O(N)$
ZRP	Hybrid, distance vector, link state	Reduced communication overhead	Overlapping zones	$O(L) + O(e)$	$O(N)$

N- Total number of mobile nodes in the network.

e- Number of communication pairs.

M- Average number of nodes in the cluster.

H- Number of hierarchical levels of HSR.

L- Average number of nodes in the local scope.

III. Routing Challenges

Even being the one of the most popular field of study, it still faces a number of routing challenges as shown in fig. 5, that are discussed below:

A. Scalability

Scalability aims at providing acceptable level of service even in the presence of large number of nodes in the network. In non-cooperative environment, where omni-directional antennas are used, throughput decreases at the data rate, where N is the number of nodes. That is, for a network consisting of 100 nodes, a single device gets approximately one-tenth of the theoretical data rate. This problem can be solved by using smart antennas instead of Omni-directional antennas. For ad hoc network route acquisition, service location, and encryption key exchange are some of the tasks which increases overhead with increase in network size. Reactive routing protocols when used for large networks increase the route acquisition latency. So there is much work required to be done in order to optimize trade-off between capacity and scalability in different scenarios.

B. Quality of Service (QoS)

In mobile ad hoc network nodes are not stable so providing QoS support in such type of network is quite challenging. QoS generally aims to fulfil performance parameters such as lower delay and jitter effect, bandwidth efficiency etc. Quality in proactive can be attained easily rather than for reactive routing protocols as the routes uses various links with different quality and stability. So quality cannot be guaranteed for long time. Still various new methods to detect and report changes in connection quality are

being investigated.

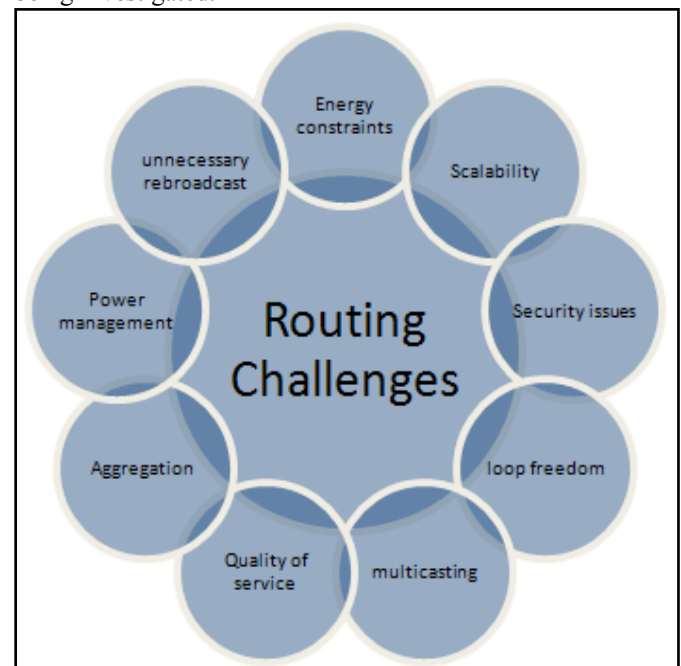


Fig. 5: Routing Challenges

C. Security

Mobile nodes are shared open and are therefore more susceptible to attacks so considering security parameters becomes the prime issue to be concerned. They are generally prone to malicious attacks such as, denial of service attack [17]. Even one of the data protecting method such as cryptographic method also faces problem of key distribution and refresh. The most serious threat that is required to be consulted is of false routing information that can paralyze the whole network even without being informed. One common approach that can be used is secure routing. However, even by adopting the most secure methods security still remains under risk.

D. Loop Freedom

Whenever routing is performed, the information that is to be send must be routed over the unique paths in order to avoid loops over the network. Otherwise it will leads to the reduce efficiency. So a well structured routing approach is desirable in order to improve performance efficiency of routing protocols.

E. Energy Constraint

Due to the portability of the network, ad hoc network generally rely on limited power sources. In spite of having better batteries and hardware with lower power consumption still most desired solution for saving battery consumption revolves around the reduction of power used by radio transceiver which is the single largest consumer of power. While at MAC layer and above all this is controlled by putting receiver in the sleep mode. From the energy management point of view, power control and multiple antennas at the link layer are coupled with power control and scheduling at MAC layer, and with energy- constrained and delay- constrained at network layer.

F. Multicasting

In ad hoc network, any node can join or leave the network any time. So the multicast tree keep on changing (i.e. do not remain static) over time. So the routing strategy must be designed in the manner so as to cope up with the mobility.

IV. Conclusion

This paper revealed that a great work regarding routing in MANETs have been done but still there are several issues in MANETs that need to be considered. Routing being one of the challenges requires special attention for improving efficiency in the communication. By analyzing flat and hierarchical protocols with their features it is concluded that hierarchical protocols provide much more efficient routing as compared to flat routing because in flat routing packet is transmitted to every node between source and destination while in hierarchical routing a special node (cluster head and gateways) are responsible for packet transmission. Comparison of several routing protocols depicting their routing features, advantages and disadvantages is also summarized in this paper along with some of its associated routing challenges.

References

- [1] S. Corson, J. Macker, "Mobile Ad hoc Networking: Routing Protocol Performance Issues and Evaluation Consideration", RFC 2501, Jan. 1999.
- [2] E.M. Royer, C.K. Toh, "A Review of Current Routing Protocols Ad Hoc Mobile Wireless Networks", IEEE Personal Communications, April 1999, pp. 46-55.
- [3] G. Pei, M. Gerla, T.-W. Chen, "Fisheye State Routing: A Routing Scheme for Ad Hoc Wireless Networks", Proc. ICC 2000, New Orleans, LA, June 2000.
- [4] P. Jacquet et al., "Optimized Link State Routing Protocol", draft-ietf-manetolsr-05.txt, Internet Draft, IETF MANET Working Group, Nov. 2000.
- [5] A. Qayyum, L. Viennot, A. Laouiti, "Multipoint Relaying: An Efficient Technique for Flooding in Mobile Wireless Networks", INRIA res. rep. RR-3898, 2000.
- [6] R. G. Ogier et al., "Topology Broadcast based on Reverse-Path Forwarding (TBRPF)", draft-ietf-manet-tbrpf-05.txt, INTERNET-DRAFT, MANET Working Group, Mar. 2002.

- [7] B. Bellur and R. G. Ogier, "A Reliable, Efficient Topology Broadcast Protocol for Dynamic Networks", Proc. IEEE INFOCOM '99, New York, NY, Mar. 1999.
- [8] X. Hong, K. Xu, Mario Gerla, "Scalable Routing Protocols for Mobile Ad Hoc Networks", IEEE Network, July/August 2002.
- [9] D.B. Johnson, D.A. Maltz, T. Imielinski, H. Korth, "Dynamic Source Routing in Ad Hoc Wireless Networks", Mobile Computing, Eds., Ch. 5, Kluwer, 1996, pp. 153-81.
- [10] C. E. Perkins E. M. Royer, "Ad-Hoc On-Demand Distance Vector Routing", Proc. IEEE WMCSA '99, New Orleans, LA, Feb. 1999, pp. 90-100.
- [11] M. Abolhasan, T. Wysocki, E. Dutkiewicz, "A review of routing protocols for mobile ad hoc networks", Elsevier, Ad-Hoc Networks 2 (2004) pp. s1-22.
- [12] Geetha Jayakumar, G. Gopinath, "Ad-Hoc Mobile Wireless Networks Routing Protocols – A Review", Journal of Computer Science, pp. 574-582, 2007.
- [13] Jyoti Jain et al., "Overview and Challenges of Routing Protocol and MAC Layer in Mobile Ad-Hoc Network", Journal of Theoretical and Applied Information Technology, 2009.
- [14] S. Chakrabarti, A. Mishra, "QoS Issues in Ad-Hoc Wireless Network", IEEE Commun. Mag., Vol. 39, No. 2, Feb. 2001.
- [15] J.A. Stine, G. Vaciana, "A comprehensive energy conservation solution for mobile Ad-Hoc network", IEEE International Conference, 2002.
- [16] H. Yang, Haiyun, Fan Ye, "Security in mobile Ad-Hoc networks: Challenges and Solutions", pp. 38-47, Vol 11, Feb 2004.
- [17] Ajay Jangra et al., "Security Aspects in Mobile Ad Hoc Networks (MANETs): A Big Picture", International Journal of Electronics Engineering, 2(1), 2010, pp. 189-196.



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