ISSN:2231-0711

Amithineni Jyothsna et al | IJCSET |April 2013 | Vol 3, Issue 4, 129-134

Cognitive Radio Wireless Mesh Networks: A Survey on Routing Protocols

Amithineni Jyothsna[1] Ch.V.Phani Krishna[1] Pavan Kumar T[1] Rajasekhara Rao K[1] V.Samson Deva Kumar[2]

[1]Department of Computer Science and Engineering
K L University, Vaddeswaram,Andhra Pradesh
[2]Project Manager in SCRWWO,
S/W Training and Development center, E-world, Vijayawada, Andhra Pradesh

Abstract: Cognitive radio (CR) technology enables the opportunistic use of the vacant licensed frequency bands and henceforth improving the spectrum utilization. Cognitive radio networks (CRNs) are composed of cognitive, spectrum-agile devices which are capable of changing their configurations depending upon the spectral environment which they use. This capability opens up the possibility of designing flexible and dynamic spectrum access strategies with the purpose of opportunistically reusing portions of the spectrum temporarily vacated by licensed primary users. On the other hand, the flexibility in the spectrum access phase comes with an increased complexity in the design of communication protocols at different layers. An extensive overview of the research in the field of routing for Cognitive radio networks differentiating the two main categories: approaches based on a full spectrum knowledge, and approaches that consider only local spectrum knowledge obtained via distributed procedures and protocols is been provided in this report.

1. INTRODUCTION:

Wireless mesh networks (WMN) are highly used low cost networks. Now a day's wireless mesh networks are mostly used in local area networks (LAN), wide area networks (WAN) and metropolitan area networks (MAN). Due to their high connectivity and better performance people prefer these types of networks everywhere like broadband home networking, community and neighborhood networks, enterprise networks and building automation. [26] Mesh connectivity substantially improves network performance like load balancing, fault tolerance, protocol efficiency and throughput. The WMN support adhoc networks and have a capability of self-healing, self-forming and self-organization [26]. In wireless mesh networks every mesh router acts as well as mesh client but every mesh client will not act as mesh router. The unique feature of mesh nodes is they are highly mobile, due to this; the nodes keep on changing their network topology. Typically, a WMN consists of static wireless mesh routers which are also known as access points (AP's) [27], these static mesh routers will form backbone of WMN and serve the mesh and conventional clients. Each AP connects mobile nodes to the wired network through multihop wireless routing. The mesh nodes are directly connected to the wired network through AP [29].

The definition of wireless mesh network varies from type to type. The definition is explained based upon the architecture used. There are 3 different types of architectures in wireless mesh networks:

1.) Infrastructure/ backbone WMN's
2.) Client WMN's
3.) Hybrid WMN's

Infrastructure/ backbone WMN's only mesh routers are used. These are mainly used to form a backbone to the clients which are connected to them. Infrastructure/backbone WMN's are most commonly used in community and neighborhood networks which are able to build infrastructure meshing. [26] In this type of meshing the routers are placed on the top of the buildings which provide the internet access to the person inside the building and people on the roads. The client wireless meshing is mainly used to provide peer to peer networks to the clients. In this type of meshing the client nodes establish the actual network to perform routing and Configurations in order to provide user applications to the customers. Compared with the infrastructure/backbone WMN's the end user requirements are increased to perform additional functionalities like self-healing and self configuring. The combination of infrastructure/ backbone WMN's and client WMN's resulted as hybrid WMN's. This hybrid WMN's is mainly used to provide access to the cellular networks, Wi-Fi, WiMax, sensor networks. Compared to the infrastructure and client meshing the routing capabilities are increased in hybrid WMN's which provide the better connectivity and coverage. [28][29][30]

Cognitive Radio Networks:

Next Generation (xG) communication networks, also known as Dynamic Spectrum Access Networks (DSANs) as well as cognitive radio networks will provide high bandwidth to mobile users through heterogeneous wireless architectures and dynamic spectrum access techniques. Before discussing about the cognitive radio networks let us know about cognitive radio. Cognitive radio means *a radio system whose parameters are changing dynamically according to the external environment.* By using the several cognitive radios' in the network they built cognitive radio networks. Cognitive radio networks is the developing area for wireless technology the main aim of the cognitive radio networks is increasing of the spectrum utilization [31][32].

The network mainly consisting of two types of users they are licensed users and unlicensed users. Licensed users are also known as primary users (PU) and unlicensed users are known as secondary user (SU).secondary user's access spectrum conditionally that means when primary users are inactive [33].

Cognitive radio had two characteristics they are Cognitive capability, Reconfigurability. Cognitive capability means the ability of the radio that can capture or sense the environment. Cognitive capability gives the awareness of the spectrum where as reconfigurability configuration of the radio to that environment (dynamically programmed).

The cognitive capability of a cognitive radio allows real time communication with its environment to find considerable communication parameters and adapt to the dynamic radio environment.

The steps are in the cognitive cycle mainly consisting of *spectrum sensing, spectrum analysis* and finally *spectrum decision.*

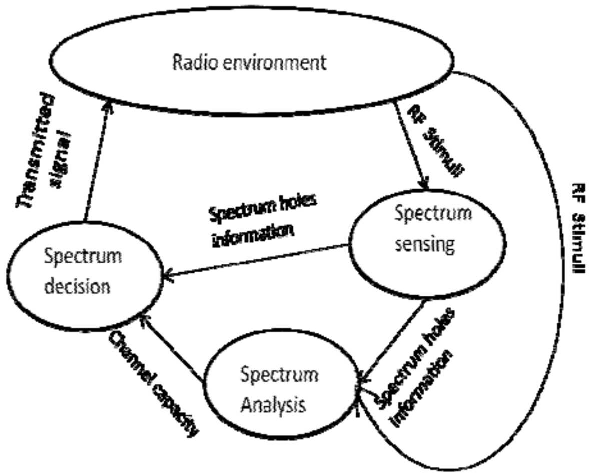

Figure-1: Cognitive wireless networks cycle

1. Spectrum sensing: A cognitive radio observes the available spectrum bands, captures their data, and then finds the white spaces.

2. Spectrum analysis: The characteristics of the spectrum holes that are detected through spectrum sensing are estimated.

3. Spectrum decision: A cognitive radio finds the data rate, the transmission mode, and the Bandwidth of the transmission. Then, the appropriate spectrum band is selected according to the Spectrum properties and user requirements.

Reconfigurability is the capability of arranging parameters for the transmission on the fly without any modifications on the hardware components. This Capability of cognitive WMN is able to adapt easily to the dynamic radio environment. There are several reconfigurable parameters as follows:

- **Operating frequency:** A cognitive radio has the ability of changing the operating frequency.
- **Modulation:** A cognitive radio should reconfigure the modulation scheme adaptive to the user requirements and channel conditions.
- **Transmission power:** Transmission power can be reconfigured within the power constraints.
- **Communication technology:** A cognitive radio can also be used to provide interoperability among different communication systems.

2. RELATED WORK:

The protocols are classified based on the their topology or geostationary based information mainly, we provide information about all the available protocols for wireless mesh networks.

2.1. Proactive protocols:

The proactive protocol is also known as table driven routing protocol. These protocols work by periodically exchanging the knowledge of topology among all the nodes of the network. The proactive protocols do not have initial route discovery delay but consumes lot of bandwidth for periodic updates of topology. There are several routing protocols that fall under this category.

Fisheye state routing (FSR): [1] it is similar to LSR. Each node maintains a topology table based on the latest information received from neighborhood nodes. It uses different exchange period for different entries in routing table to reduce the size of control messages in large networks. The disadvantage in FSR routing is the size of the routing table increases with increase in network size. Route discovery may fail if the destination node lies out of scope of source node. Due to high mobility in VANET route to remote destination become less accurate.

Optimized Link State Routing Protocol (OLSR): [2] it is an optimization of a pure link state protocol for mobile ad hoc networks. Each node in the network selects a set of neighbor nodes called as multipoint relays (MPR) which retransmits its packets. The neighbor nodes which are not in its MPR set can only read and process the packet. This procedure reduces the number of retransmissions in a broadcast procedure

Topology Dissemination Based on Reverse-Path Forwarding (TBRPF): [3] is a link-state routing protocol designed for ad-hoc networks. Every node constructs a source tree which contains paths to all reachable nodes by using topology table. Nodes are periodically updated with only the differences between the previous and current network state using HELLO messages. Therefore, routing messages are smaller, can therefore be sent more frequently to neighbors.

2.2. Reactive protocols:

These protocols are called as on-demand routing protocols as they periodically update the routing table, when some data is there to send. But these protocols use flooding process for route discovery, which causes more routing overhead and also suffer from the initial route discovery process, which make them unsuitable for safety applications in VANET.

AODV: [4] is a source initiated routing protocol and uses HELLO messages to identify its neighbors. Source node broadcasts a route request to its neighbors which fill forward to the destination. Then the destination unicast a route reply packet to the sender. Every node maintains broadcast-id which increments for new RREQ .when a RREQ arrives at a node, it checks the broadcast_id if it is less than or equal to previous message then it will discard the packet.

DSR: [5] uses source routing instead of depending on intermediate node routing table. So routing overhead is always dependent on the path length. . The limitation of this protocol is that the route maintenance process does not locally repair a broken link. The performance of the protocol briskly decreases with increasing mobility.

Temporally-Ordered Routing Algorithm (TORA): [6] each node constructs directed cyclic graph by broadcasting query packets. On receiving a query packet, if node has a route to destination it will send a reply packet; else it drops the packet. A node on receiving a reply packet will update its height only if the height of packet is minimum than other reply packets. It gives a route to all the nodes in the network, but the maintenance of all these routes is difficult in VANET.

2.3. Hybrid protocol:

The hybrid protocols are introduced to reduce the control overhead of proactive routing protocols and decrease the initial route discovery delay in reactive routing protocols.

Zone routing protocol (ZRP): [7] in this the network is divided into overlapping zones. The zone is defined as a collection of nodes which are in a zone radius. The size of a zone is determined by a radius of length α where α is the number of hops to the perimeter of the zone. In ZRP, a proactive routing protocol (IARP) is used in intra-zone communication and an inner-zone reactive routing protocol (IARP) is used in intra-zone communication. Source sends data directly to the destination if both are in same routing zone otherwise IERP reactively initiates a route discovery.ZRP aims to find loop free routes to the destination. It uses bordercasting method to construct multicast trees to flood the query packets instead of standard flooding to discover the destination route.

HARP: [8] divides entire network into non-overlapping zones. It aims to establish a stable route from a source to a destination to improve delay. It applies route discovery between zones to limit flooding in the network, and choose best route based on the stability criteria. In HARP routing is performed on two levels: intra-zone and inter-zone, depending on the position of destination. It uses proactive and reactive protocols in intra-zone and inter-zone routing respectively. It is not applicable in high mobility adhoc networks.

3. POSITION BASED PROTOCOLS:

These protocols use geographic positioning information to select the next forwarding hops so no global route between source and destination needs to be created and maintained.

Greedy Perimeter Stateless Routing (GPSR): [9] Each node periodically broadcasts a beacon message to all its neighbors containing its id and position. If any node does not receives any beacon message from a neighbor for a specific period of time, then GPSR router assumes that the neighbor has failed or out-of-range, and deletes the neighbor from its table. It takes greedy forwarding decisions using information about immediate neighbors in the network. For any node if greedy forwarding is impossible then it uses perimeter of the region strategy to find the next forwarding hop. In a city scenario greedy forwarding is often restricted because direct communications between nodes may not exist due to obstacles such as buildings and trees. Converting network topology into planarized graph when greedy forwarding is not possible will degrade the performance of routing.

The authors [10] eliminated graph planarization in Greedy Perimeter Coordinator Routing (GPCR) it consists of two parts: a restricted greedy forwarding procedure and a repair strategy which is based on the topology of real-world streets and junctions and hence does not require a graph planarization process. The GPCR takes advantage of the fact that streets and junctions form a natural planar graph, without using any static street map.

MIBR: [11] protocol use buses as a key element in route selection and data transfer process. While designing the protocol quality of transmission for each road segment and different transmission abilities of various vehicles are also considered. It measures the density of every road segment using bus line information. MIBR is a location based reactive routing protocol. Source node uses GPS system to get the destination information. Each bus contains two heterogeneous wireless interfaces and other vehicles have single interface. While routing it estimates next road segment and hop count and stored in a route table. The next road segment is chosen when the packet is near a junction. This process consumes less bandwidth. In packet forwarding process it uses "bus first" strategy. MIBR is only suitable in urban scenarios.

GYTAR: [12] is an improved Greedy Traffic Aware Routing Protocol for Vehicular Ad Hoc Networks in City Environments. It contains two modules: Junctions selection, forwarding data between two junctions. A packet will pass through junctions to reach its destination. In junction selection process a value is given to each junction by comparing the traffic density between the current junction and the next candidate junction and the curvemetric distance to the destination. The junction with highest value will be chosen for packet forwarding. In second module each vehicle maintains a table which contains position, velocity and direction of each neighbor vehicle and the table is updated periodically. Thus, when a packet is received, the forwarding vehicle computes the new predicted position of each neighbor using the table and then selects the next hop neighbor which is closer to the destination junction which may cause packets in a local optimum. To overcome this problem GYTAR uses store and forward strategy. In this strategy packet will be stored at the intermediate node until another vehicle which is closer to the destination junction enters in its transmission range. Due to high mobility in VANET all greedy forwarding protocols can also cause routing loops problem and some packets may get forwarded to the wrong direction.

4. GEOCAST BASED PROTOCOLS:

These protocols are used to send a message to all vehicles in a pre-defined geographical region.

Robust Vehicular Routing (ROVER): [13] it is a reliable geographical multicast protocol where only control packets are broadcasted in the network and the data packets are unicasted. The objective of the protocol is to send a message to all other vehicles within a specified Zone of Relevance (ZOR). The ZOR is defined as a rectangle specified by its corner coordinates. A message is defined by the triplet [A, M, Z] indicates specified application, message, identity of a zone respectively. When a vehicle receives a message, it accepts the message if it is within the ZOR. It also defines a Zone of Forwarding (ZOF) which includes the source and the ZOR. All vehicles in the ZOF are used in the routing process. It uses a reactive route discovery process within a ZOR. This protocol creates lot of redundant messages in the network which leads to congestion and high delay in data transfer. To overcome this problem authors [14] proposed a Two Zone Dissemination Protocol for VANET. It uses hop-count in packet and is decremented when the packet is forwarded. If the hop-count reaches to zero the packet will be discarded. It causes nodes near to the sender forward a packet multiple times. To avoid it they introduced sequence number for every packet to detect whether a packet has been received before or not.

DTSG: [15] The main aim of this protocol is to work even with sparse density networks. It dynamically adjusts the protocol depending on network density and the vehicles speed for better performance. It defines two phases: pre-stable and stable period. Pre-stable phase helps the message to be disseminated within the region, and stable-period intermediate node uses store and forward method for a predefined time within the region. It also tries to balance between packet delivery ratio and network cost.

5. CLUSTER BASED PROTOCOLS:

In Cluster-based routing protocols vehicles near to each other form a cluster. Each cluster has one cluster-head, which is responsible for intra and inter-cluster management functions. Intra-cluster nodes communicate each other using direct links, whereas inter-cluster communication is performed via cluster-headers. In cluster based routing protocols the formation of clusters and the selection of the cluster-head is an important issue. In VANET due to high mobility dynamic cluster formation is a towering process.

HCB [16] is a novel based Hierarchical Cluster routing protocol designed for highly mobility adhoc networks. HCB is two-layer communication architecture. In layer-1 mostly nodes have single radio interface and they communicate with each other via multi-hop path. Among these nodes some also have another interface with long radio communication range called super nodes which exist both on layer-1and 2. Super nodes are able to communicate with each other via the base station in layer-2. During the cluster formation, each node will attach to the nearest cluster header and super nodes will become cluster headers in layer-1. In HCB, intra-cluster routing is performed independently in each cluster. Cluster heads exchange membership information periodically to enable inter-cluster routing.

Cluster Based Routing (CBR): [17] The geographic area is divided into square grids. Each node calculates optimal neighbor cluster header to forward data to the next hop by using geographic information. The routing overhead is less as it need not discover route and save in routing table. The cluster header broadcasts a LEAD message to its neighbors with coordinate of its grid and the location of cluster header. If there is a road side unit (RSU) in the grid it will become a cluster header. Whenever the header is leaving the grid, it will broadcast LEAVE message containing of its grid position, an intermediate node stores it until a new cluster header is selected. The new cluster header uses this information for data routing. This protocol does not consider velocity and direction which are important parameters in VANET.

Cluster-Based Directional Routing Protocol (CBDRP): [18] It divides the vehicles into clusters and vehicles which are moving in same direction form a cluster. The source sends the message to its cluster header and then it forwards the message to header which is in the same cluster with the destination. At last the destination header sends the message to the destination. The cluster header selection and maintenance is same like CBR but it considers velocity and direction of a vehicle.

6. BROADCAST BASED PROTOCOLS:

Edge-aware epidemic protocol (EAEP): [19] is a reliable, bandwidth-efficient information dissemination based highly dynamic VANET. It reduces control packet overhead by eliminating exchange of additional "hello" packets for message transfer between merging clusters of vehicles and cluster maintenance. Each vehicle piggybacks its own geographical position to broadcast messages to eliminate beacon messages. Upon receiving a new rebroadcast message, EAEP uses number of transmission from front nodes and back nodes in a given period time to calculate the probability for making decision whether nodes will rebroadcast the message or not. By this mechanism, at the edge of each transmission will be preferred area to rebroadcast messages. But EAEP does not address the intermittent-connectivity issue. Specifically, a node does not know whether it has missed any messages to its new neighbors have or its neighbors have missed some messages. EAEP overcomes the simple flooding problem but it provides high delay of data dissemination.

Distributed vehicular broadcast protocol (DV-CAST): [20] It uses local topology information by using the periodic hello messages for broadcasting the information. Each vehicle uses flag variable to check whether the packet is redundant or not. This protocol divides the vehicles into three types depending on the local connectivity as well-connected, sparsely connected, totally disconnected neighborhood. In well-connected neighborhood it uses persistence scheme (weighted p-persistence, slotted 1and p persistence). In sparsely connected neighborhood after receiving the broadcast message, vehicles can immediately rebroadcast with vehicles moving in the same direction. In totally disconnected neighborhood vehicles are used to store the broadcast message until another vehicle enters into transmission range otherwise if the time expires it will discard the packet. This protocol causes high control overhead and delay in end to end data transfer.

Secure Ring Broadcasting (SRB): [21] It is to minimize number of retransmission messages and to get more stable routes. It classifies nodes into three groups based on their receiving power as Inner Nodes (close to sending node), Outer Nodes (far away from sending node), Secure Ring Nodes (preferable distance from sending node). It restricts rebroadcasting to only secure ring nodes to minimize number of retransmissions.

PBSM: [22] is an adaptive broadcasting protocol that does not require nodes to know about position and movement of their nodes and itself. It uses connected dominating sets (CDS) and neighbor elimination concepts to eliminate redundant broadcasting. It employs two-hop neighbor information obtained by periodic beacons to construct CDS. Each vehicle A maintains two lists of neighboring vehicles: R and NR, containing neighbors that already received and that which did not receive the packet. After a timeout, A rebroadcasts the packet if the list NR is nonempty. Both lists R and NR are updated periodically by using beacon messages. Nodes in CDS have less waiting timeout than nodes that are not in CDS. The main idea of PBSM is two nodes do not transmit every time they discover each other as new neighbors. It is a parameter less protocol which does not consider vehicle position, direction and velocity. To overcome this problem authors proposed ACKPBSM [23] tries to reduce the protocol redundancy in VANET. It uses GPS to retrieve position information and acknowledgements are piggybacked in periodic beacon messages. It employs 1-hop position information obtained by periodic beacons to construct CDS.

As PBSM AND ACKPBSM uses store-and-forward method to deliver the message in whole network which employs high end to end delay this is not acceptable in safety application for VANET.

8. Comparsion Of Routing Protocols

The various protocols are compared based on important parameters are tabulated below.

Parameters / Protocols	Forwarding strategy	Routing Maintenance	Recovery strategy	Infrastructure Requirement	Control Packet overhead	No of retransmission
FSR	Multi hop	Proactive	Multi hop	No	High	Less
OLSR	Multi hop	Proactive	Multi hop	No	High	Less
TBRPF	Multi hop	Proactive	Multi hop	No	High	Less
AODV	Multi hop	Reactive	Store and Forward	No	Low	Less
DSR	Multi hop	Reactive	Store and forward	No	Low	Less
TORA	Multi hop	Reactive	Store and forward	No	Low	Less
ZRP	Multi hop	Hybrid	Multi hop	No	Moderate	Less
HARP	Multi hop	Hybrid	Multi hop	No	Moderate	Less
GPSR	Greedy forwarding	Reactive	Store and forward	No	Moderate	Less
GPCR	Greedy Forwarding	Reactive	Store and forward	No	Moderate	Less
MIBR	Bus first	Reactive	Store and forward	No	Low	Moderate
GYTAR	Greedy forwarding	Reactive	Store and forward	No	Moderate	Less
ROVER	Multi hop	Reactive	Flooding	No	High	High
TZDP	Multi hop	Reactive	Flooding	No	Low	High
DTSG	Multi hop	Reactive	Flooding	No	Moderate	High
HCB	Multi hop	Reactive	Store and forward	No	Moderate	High
CBR	Multi hop	Reactive	Store and forward	No	Moderate	High

CONCLUSION:

This paper discusses the various routing protocols proposed for VANET. Routing is an important component in vehicle to vehicle (V2V) and infrastructure to vehicle (I2V) communication. In most applications position based, geocast and cluster based protocols are more reliable. The performance of VANET routing protocols depend on various parameters like mobility model, driving environment and many more. Designing a routing protocol for all VANET applications is very hard. Hence a survey of different VANET protocols, comparing the various features is absolutely essential to come up with new proposals for VANET.

REFERENCES:

[1] M. Gerla, X. Hong, G. Pei, "Fisheye State Routing Protocol (FSR)", IETF Internet Draft, work in progress, draft-ietf-manet-fsr-03.txt, July 2002

[2] T. Clausen, et al., "Optimized Link State Routing Protocol (OLSR)," RFC 3626, Network Working Group, Oct. 2003

[3] R. Ogier, et al., "Topology Dissemination Based on Reverse-Path Forwarding (TBRPF)," RFC 3684, Network Working Group, Feb. 2004

[4] C. Perkins, E. Belding-Royer, and S. Das, "Ad Hoc On-Demand Distance Vector (AODV) Routing," RFC 3561, Network Working Group, 2003

[5] D. Johnson, B., D. A. Maltz, and Y.-C. Hu, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)," draft-ietf-manet-dsr-10.txt, 2004

[6] V. Park, S. Corson, "Temporally-Ordered Routing Algorithm (TORA) Version 1 Functional Specification", IETF Internet draft, work in progress, draft-ietf-manet-tora-spec-04.txt, 2001

[7] Z. J. Haas. The Zone Routing Protocol (ZRP) for ad hoc networks, Internet Draft, Nov. 1997.

[8] Navid Nikaein, Christian Bonnet and Neda Nikaein, HARP - Hybrid Ad Hoc Routing Protocol, in proceeding of IST 2001: International Symposium on Telecommunications, Iran/Tehran 2001.

[9] B. Karp and H.T. Kung, GPSR: Greedy perimeter stateless routing for wireless networks, in Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom)[C],2000.

[10] C. Lochert, M. Mauve, H. Füßler, and H. Hartenstein, Geographic routing in city scenarios, ACM SIGMOBILE Mobile Computing and Communications Review (MC2R) [C], vol. 9, no. 1, pp. 69-72, Jan.2005.

[11] Jie Luo, Xinxing Gu, Tong Zhao, Wei Yan, "A Mobile Infrastructure Based VANET Routing Protocol in the Urban Environment," IEEE Conference on Communications and Mobile Computing,2010.

[12] Moez Jerbi, Rabah Meraihi, Sidi-Mohammed Senouci, Yacine Ghamri-Doudane ENSIIE," GyTAR: improved Greedy Traffic Aware Routing Protocol for Vehicular Ad Hoc Networks in City Environments," *VANET'06,* September 29, 2006, Los Angeles, California, USA.,ACM 1-59593-540-1/06/0009.

[13] M. Kihl, M. Sichitiu, T. Ekeroth and M. Rozenberg , "Reliable Geographical Multicast Routing in Vehicular Ad-hoc Networks," Lecture Notes in Computer Science 4517 LNCS[C], pp. 315-325. 2007.

[14] Jeppe Bronsted and Lars Michael Kristensen, "Specification and Performance Evaluation of Two Zone Dissemination Protocols for Vehicular Ad-hoc Networks," IEEE Proceedings of the 39th Annual Simulation Symposium (ANSS'06).

[15] Hamidreza Rahbar, Kshira sagar Naik, Amiya Nayak, "DTSG: Dynamic Time-Stable Geocast Routing in Vehicular Ad Hoc Networks," IEEE Symposium on Computers and Communications, 2001, pp. 198–203.

[16] Yang Xia, Chai Kiat Yeo, Bu Sung Lee," Hierarchical Cluster Based Routing for Highly
Mobile Heterogeneous MANET," Communications and Information Technologies, 2007. ISCIT '07. International Symposium on, pp. 936–941, Oct. 2007.

[17] Yuyi Luo, Wei Zhang, Yangqing Hu," A New Cluster Based Routing Protocol for VANET," IEEE Wireless Communications and Trusted Computing, 2010.

[18] Tao Song, Wei Wei Xia, Tiecheng Song, Lianfeng Shen,"A Cluster-Based Directional Routing Protocol in VANET," International Conference on Communication and Mobile Computing, 2010: 259-265

[19] M. Nekovee, B. BjamiBogason, "Reliable and efficient information dissemination in intermittently connected vehicular ad hoc networks," IEEE the 65th VTC'07 spring, Dublin, Ireland, April 22-25, 2007.

[20] O. K. Tonguz, N. Wisitpongphan, F. Bai, P. Mudalige and V. Sadekar, "Broadcasting in VANET," Proc. IEEE INFOCOM MOVE Workshop 2007, Anchorage, USA, May, 2007.

[21] Rainer Baumann," Vehicular Ad hoc Networks" Master's Thesis in Computer Science, ETH Zurich 2004

[22] Adnan Afsar Khan, Ivan Stojmenovic, Nejib Zaguia, "Parameterless broadcasting in static to highly mobile wireless ad hoc, sensor and actuator networks," in Proc. ACM Int.Conference on Mobile Computing and Networking (MobiCom), Seattle, USA, August 1999

[23] F. 1. Ros, P. M. Ruiz, and I. Stojmenovic, "Reliable and efficient broadcasting in vehicular ad hoc networks," IEEE the 69th Vehicular Technology Conference (VTC'09), Barcelona, Spain, April 26-29, 2009.

[24] Y. Ding, C.Wang, and L. Xiao, "A static-node assisted adaptive routing protocol in vehicular networks," VANET'07: Proceedings of the fourth ACM international workshop on Vehicular ad hoc networks, pages 59–68, September 2007.

[25] A New Routing Protocol In Cognitive Wireless Mesh Networks Xuebin Sun, Yurong Zhang, Chenglin Zhao Wireless Network Laboratory, Key Laboratory Of Universal wireless Communications, Ministry Of Education Beijing University Of Posts And Telecommunications, Beijing, China

[26] "Wireless mesh networks: a survey" Ian F. Akyildiz , Xudong Wang , Weilin Wang Broadband and Wireless Networking (BWN) Lab, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA January 2005

[27] Design and analysis of mobility aware clustering algorithms for wireless mesh networks, IEEE/ACM transactions on networking, vol 18, No. 6, December 2010.

[28] "Building a rural wireless mesh network" by David Johnson, karel mathee, Dare Sokoya, Lawrence mboweni, Ajay Makan, and Henk Kotze Meraka Institute South Africa 30 Oct 2007.

[29] D. De Couto, D. Aguayo, J. Bicket, and R.Morris. "High-throughput path metric for multi-hop wireless routing."In MOBICOM, 2003

[30] Ian F. Akyildiz, et al, "NeXt generation /dynamic spectrum access/cognitive radio wireless networks:Asurvey",Computer Networks, May,2006

[31] Geng Cheng, Wei Liu, Yunzhao Li, and Wenqing Cheng, "Joint On-demand Routing and Spectrum Assignment in Cognitive Radio Networks" IEEE.ICC.2007

[32] Xin C, Xie B, and Shen C. "A novel layered graph model for topology formation and routing in dynamic spectrum access networks"[C]. DySPAN 2005, Baltimore, MD, United States, 2005: 308-317

[33] Yang, Y. and Wang, J., "Design guidelines for routing metrics in multihop wireless networks", IEEE INFOCOM, 2008.