Comparison and Analysis of Pro-Active Routing Protocols in MANET

Deeptanoy Ghosh[1], Poonam Thakur[2]
[1, 2](CSE, Lovely Professional University, Phagwara, India

ABSTRACT

Mobile Ad hoc wireless networks are characterized by infrastructure less environment, multi-hop wireless connectivity and frequently changing topology. Wireless links are highly error prone and can go down frequently due to mobility of nodes. So stable routing is a very critical task due to highly dynamic environment in ad-hoc wireless networks. The identification of stable and efficient routing protocol plays a very critical role in places where wired network are neither available nor economical to deploy. In this paper, comparison and behavioral study of different MANET pro-active routing protocols such as DSDV, WRP, CGSR, GSR, DREAM, STAR, HSR, TBRPF, FSR, LANMAR, OLSR, and HOLSR have been carried out so as to identify which protocol is most suitable for efficient routing over mobile ad-hoc network (MANET). This paper provides an overview with advantages and disadvantages of these pro-active routing protocols by presenting their comparative analysis.

Keywords: DSDV, WRP, LANMAR, CGSR, FSR, OLSR, HOLSR.

I. INTRODUCTION

Pro-active routing protocols [1] [2] [3] [4] require each node to maintain up-to-date routing information to every other node in the network. The various routing protocols in this group differ in how topology changes are detected, how routing information is updated and what sort of routing information is maintained at each node. These routing protocols are based on the working principles of two popular routing algorithms used in wired networks. They are known as link-state routing and distance vector routing. In the link-state approach, each node maintains at least a partial view of the whole network topology. Each node periodically broadcasts link-state information such as link activity and delay of its outgoing links to all other nodes using network-wide flooding. After receiving the information, the node updates its view of the network topology and applies a shortest-path algorithm to choose the next hop for each destination. On the other hand, each node in distance vector routing periodically monitors the cost of its outgoing links and sends its routing table information to all neighbors.

II. THE NEED AND SPECIALITY OF PRO-ACTIVE ROUTING PROTOCOLS

Routing in wireless network is difficult since mobility causes frequent network topology changes and requires more robust and flexible mechanisms to search for and maintain routes. With a changing topology, even maintaining connectivity is very difficult. Besides handling the topology changes, these protocols must deal with other constraints (low bandwidth, limited power consumption, high error rates). Proactive methods maintain routes to all nodes. These protocols include nodes to which no packets are sent. They react to topology changes, and no traffic is affected by the changes. These methods also called table-driven methods. Proactive routing protocols maintain routes to all destinations, instead of whether or not these routes are needed. The main advantage of this category of protocols is that hosts can quickly obtain route information and quickly establish a session.

III. OVERVIEW OF VARIOUS PRO-ACTIVE ROUTING PROTOCOLS

Pro-active routing protocols can be divided into two sub-groups based on the routing structure: (1) flat and (2) hierarchical. In flat routing protocols nodes are addressed by a flat addressing scheme. In flat addressing scheme each node plays an equal role in the network. On the other hand, different nodes have different routing responsibilities in hierarchical routing protocols. Routing protocols require a hierarchical addressing system to address the nodes.

A. Destination-Sequenced Distance-Vector (DSDV) Routing

Destination-Sequenced Distance-Vector Routing protocol [6] [7] [8] is a distance vector routing protocol that define loop-free routing by tagging each route table entry with a sequence number. The protocol requires each node to maintain a routing table. Each entry, corresponding to a particular destination, contains the number of hops to reach the destination and the address of the neighbor that acts as a next-hop towards the destination. Each node periodically broadcasts updates to its neighbors to maintain the consistency of the routing tables in a dynamically varying topology. Updates are also broadcast to neighbors immediately when significant new information, such as link breakage is available.

In DSDV two modes of updates can be employed. First one is known as "full dump" where multiple network protocol data units may be needed to carry all available routing information to the neighbors. The second one is referred to as "incremental" where only routing information changed since the last "full dump" is sent in a single network protocol data unit to the neighbors. In case topological change is not rapid, "full dump" can be employed less frequently than "incremental" mode to reduce network traffic.

Advantages:

1. This protocol is Loop-free and simple.
2. Computationally efficient.

Disadvantages:

1. Due to network-wide periodic and triggered update requirements, DSDV introduces excessive communication overhead.
2. DSDV may engage in prolonged exchanges of distance information before converging to shortest paths after a link failure. These problems can become unacceptable if network size or node mobility increases.
3. Slow convergence.
4. Tendency to create routing loops in large networks.

B. Wireless Routing Protocol (WRP)

Wireless Routing Protocol [8] [9] [10] is another distance vector routing protocol that aims to reduce the possibility of forming temporary routing loops in MANET. WRP belongs to a subclass of the distance vector protocol known as the path-finding algorithm that Routing Protocols for Ad-Hoc Networks eliminates the counting-to-infinity problem of distributed Bellman Ford. Each node obtains the shortest-path spanning tree to all destinations of the network from each one-hop neighbor in a path-finding algorithm. A node uses this information along with the cost of adjacent links to construct its own shortest-path spanning tree for all destinations. Each node in WRP maintains a distance table, a link-cost table, a routing table and a message retransmission list. WRP requires each node to exchange routing tables with its neighbors using update messages periodically as well as after the status of one of its links changes.

Advantages:

1. Fewer nodes are informed in WRP than in DSDV during a link failure. Hence WRP can find shortest path routes faster than DSDV.
2. Loop free.
3. Lower WTC than DSDV.

Disadvantages:

1. WRP does not allow nodes to enter into a sleep mode to conserve energy.

C. Clusterhead Gateway Switch Routing (CGSR)

Clusterhead Gateway Switch Routing protocol [11] [12] [13] is a hierarchical routing protocol that uses DSDV as its underlying routing algorithm. It reduces the size of routing update packets in wide networks by partitioning the whole network into multiple clusters. CGSR uses only one level of clustering hierarchy. In CGSR, each cluster contains a clusterhead. Clusterhead manages all nodes within its radio transmission range. A node that belongs to more than one cluster works as a gateway to connect the overlapping clusters. In CGSR there are two tables maintained: a routing table and a member table. The routing table maintains only one entry for each clusterhead. Each entry in the routing table contains the address of a clusterhead and the address of the next hop to reach the clusterhead. The cluster member table records the clusterhead address for each node in the network and broadcast it periodically.

Advantages:

1. CGSR reduces the size of the routing table as well as the size of routing update messages.
2. Since each node only maintains routes to its clusterhead in CGSR, routing overhead is lower than compared to DSDV and WRP.
3. Simpler addressing scheme compared to MMWM.

Disadvantages:

1. Since additional time is required to perform clusterhead reselection, time to recover from link failure is higher than DSDV and WRP.

D. Global State Routing (GSR)

Global State Routing [14] [15] is the modification of link-state algorithm by adopting the routing information dissemination method used in DBF. Instead of flooding, GSR transmits link-state updates to neighboring nodes. Each node in GSR protocol maintains a neighbor list, a next-hop table, a topology table and a distance table. Whenever a node receives a routing message containing link-state updates from one of its neighbors, it updates its topology table if the timestamp is newer than the ones stored in the table. When the node reconstructs the routing table it broadcasts the information to its neighbors with other link-state updates.

Advantages:

1. The key difference between GSR and traditional link-state algorithms is the way routing information is disseminated.
2. A node in GSR transmits longer packets containing multiple link-state updates to its neighbors. Therefore GSR requires fewer update messages than a traditional link-state algorithm in an ad-hoc network with frequent topology alters.

Disadvantages:

1. As the network size and node density increase, the size of each update message becomes larger.

E. Distance Routing Effect Algorithm for Mobility (DREAM)

Distance Routing Effect Algorithm [16] [17] [18] for Mobility uses location information using GPS to provide loop-free multi-path routing for MANET. In DREAM, each node maintains a location table that records location information of all nodes. There are two principles in DREAM: distance effect and mobility rate. Distance effect states that the greater the distance between two nodes the slower they appear to move with respect to each other. The mobility rate states another interesting observation that the faster a node moves, it needs to advertise its new location information to other nodes.

Advantages:

1. DREAM minimizes routing overhead by employing "distance effect" and "mobility rate".

Disadvantages:

1. DREAM requires Global Positioning System.

F. Source Tree Adapting Routing (STAR)

Source Tree Adapting Routing [19] [20] [21] is based on a link-state algorithm that minimizes the number of routing update packets disseminated into the network to save bandwidth that is reduce network traffic. Source Tree Adapting Routing protocol requires each node to maintain a source tree, which is a set of link constituting complete paths to destinations. It also derives a routing table by running Dijkstra's shortest path algorithm on its source tree. A node knows the status of its adjacent links and the source trees reported by its neighbors.

Advantages:

1. Minimizes the number of routing update packets disseminated in the network.

Disadvantages:

1. May not provide optimum routes to destinations.
2. Significant memory and processing overheads for large and highly mobile MANETs.

G. Hierarchical Star Routing (HSR)

Hierarchical Star Routing [22] [23] designed to scale well with network size. It argues that the location management that is the location updating and location finding in MMWM is quite complicated since it couples location management with physical clustering. Hierarchical Star Routing aims to make the location management task simpler by separating it from physical clustering. The protocol maintains a hierarchical topology by clustering group of nodes based on their geographical relationship. The clusterheads at a lower level become members of the next higher level. The new members then form new clusters, and this process continues for several levels of clusters. The clustering is beneficial for the efficient utilization of radio channels and the reduction of network layer overhead that is processing, routing table storage and transmission. In addition to the multi-level clustering HSR provides multi-level logical partitioning based on the functional affinity between nodes. Logical partitioning is responsible for mobility management.

Advantages:

1. In HSR nodes are also partitioned into logical partitions, that is, subnets, in order to resolve implementation problems of MMWM.
2. HSR requires less memory.

Disadvantages:

1. It introduces additional overhead like any other cluster based protocol for forming and maintaining clusters.

H. Topology Broadcast Based on Reverse Path Forwarding (TBRPF)

Topology Broadcast Based on Reverse Path Forwarding protocol [24] [25] is also a link-state based routing protocol. It uses the concept of reverse-path forwarding to broadcast link-state updates in the reverse direction along the spanning tree formed by minimum-hop paths from all nodes to the source of the update. Each node in TBRPF maintains a list of its one-hop neighbors and a topology table. Each entry in the topology table for a link contains the most recent cost and sequence number associated with that link. With this information each node can compute a source tree that provides shortest paths to all reachable remote nodes.

Advantages:

1. TBRPF generates less update traffic than pure link-state routing algorithms.
2. TBRPF requires only the non-leaf nodes in the broadcast tree to forward update packets.
3. The use of minimum-hop tree instead of a shortest-path tree makes the broadcast tree more stable.
4. Less communication cost to maintain the tree.
5. Lower WCC compared to pure link-state routing.

Disadvantages:

1. Overheads increase with node mobility and network size.

I. Fisheye State Routing (FSR)

Fisheye State Routing protocol [26] is an improvement of GSR. FSR is an implicit hierarchical routing protocol that uses the "fisheye" technique to reduce the size of large update messages generated in GSR for large networks. The scope of the fisheye of a node is defined as the set of nodes that can be reached within a given number of hops. FSR, like GSR, requires each node to maintain a neighbor list, a next hop table, a topology table and a distance table. Entries in the topology table corresponding to nodes within the smaller scope are propagated to the neighbors with higher frequency.

Advantages:

1. The fisheye approach enables FSR to reduce the size of update messages.
2. In FSR, each node can maintain fairly accurate information about its neighbors.

Disadvantages:
1. As the distance from the node increases, the accuracy and detail of information also decreases thus a node may not have precise knowledge of the best route to a distant destination.
2. GSR requires the entire topology table to be exchanged among neighbors.
3. Entire topology change can consume a considerable amount of bandwidth when the network size becomes wide.

J. Landmark Ad-Hoc Routing (LANMAR)

Landmark Ad-Hoc Routing [27] [28] [29] is a combined link-state and distance vector routing that is combination of FSR and DSDV protocol that aims to be scalable. LANMAR borrows the notion of landmark to keep track of logical subnets. Subnets can be formed in an ad-hoc network with the nodes that are likely to move as a group such as colleagues in the same organization or brigades in the battlefield. LANMAR only uses the FSR functionality when a network is formed for the first time. One of the nodes learns from the FSR tables that there it contains a certain number of nodes within its fisheye scope. It then proclaims itself as a landmark for that group. When more than one node declares itself as a landmark for the same group, the node with the largest number of group members wins the election. If there is a tie, the node with the lowest ID breaks the tie. The distance vector routing mechanism propagates the routing information about all the landmarks in the entire network. Within each subnet, a mechanism, similar to FSR, is used to update topology information. As a result, each node contains detailed topology information about all the nodes within its fisheye scope and the distance and routing vector information to all landmarks.
Advantages:
1. LANMAR reduces both routing table size and control overhead for large MANETs.
2. LANMAR guarantees the shortest path from a source to a destination if the destination is located within the scope of the source.
3. LANMAR improves routing scalability for large MANETs with the assumption that nodes under a landmark move in groups.
Disadvantages:
1. Assumption of group mobility. Nodes may not have the best route to distant destinations.

K. Optimized Link-State Routing (OLSR)

Optimized Link-State Routing [30] [31] [32] optimizes the link-state algorithm by compacting the size of the control packets that contain link-state information and reducing the number of transmissions needed to flood these control packets to the whole network. Each node maintains a topology table that represents the topology of the network built from the information obtained from the TC messages. Each node broadcasts specific control messages called the topology control (TC) messages. Each node also maintains a routing table where each entry in the routing table corresponds to an optimal route, in terms of the number of hops. Each entry consists of next-hop address, a destination address and the number of hops to the destination. In OLSR routing table is built based on the information available in the topology table and the neighbor table.
Advantages:
1. It minimizes flooding of control traffic.
2. OLSR reduces the size of the control packets since in each control packet a node puts only the link-state information of the neighboring MPRs instead of all neighbors.
3. Reduces size of update messages and number of transmissions than a pure link-state routing protocol.
Disadvantages:
1. Information of both 1-hop and 2-hop neighbors is required.

L. Hierarchical Optimized Link-State Routing (HOLSR)

Hierarchical Optimized Link-State Routing [33] [34] is a routing mechanism derived from the OLSR protocol. The main improvement realized by HOLSR over OLSR is a reduction in routing control overhead. To reduce routing control overhead, HOLSR organizes mobile nodes into multiple topology levels based on their varying communication capabilities.
Advantages:
1. Suitable for large heterogeneous MANETs.
2. All nodes do not contain information of all other nodes of the network.
3. The size of the routing tables of lower-level nodes in HOLSR is less than that of OLSR.
Disadvantages:
1. Information of both 1-hop and 2-hop neighbors is required.
2. Introduces additional overhead for forming and maintaining clusters.

IV. COMPARISONS OF THESE PROTOCOLS

Pro-active routing protocols with flat routing structures usually incur large routing overheads in terms of storage requirements and communication costs to maintain up-to-date routing information about the entire network. They may not scale well as the mobility or network size increases. DREAM reduces the transmission overhead by exchanging location information rather than full or partial link-state information. FSR has reduced the communication overhead by decreasing the frequency of updates. OLSR reduces rebroadcasting by using multipoint relays. So these flat routing protocols have better scalability. The hierarchical pro-active routing protocols reduce communication and storage overhead as the network size increases. Only the clusterheads are required to update their views of the whole network. In MANETs, group mobility is usually impossible. Hence these protocols can introduce additional complexity as well as overhead for cluster formation and maintenance of the network. Hence these protocols may not perform better than flat pro-active routing protocols. A parameter wise comparison has given below in the table.

Protocols	WCC	WTC	RS	CRITICAL NODES	FREQUENCY OF UPDATES	HM
DSDV	O(N)	O(D)	F	NO	Periodic and On-Demand	YES
WRP	O(N)	O(h)	F	NO	Periodic and On-Demand	YES
CGSR	O(N)	O(D)	H	Cluster head	Periodic	NO
GSR	O(N)	O(D)	F	NO	Periodic	NO
DREAM	O(N)	O(D)	F	NO	On-Demand	NO
STAR	O(N)	O(D)	F	NO	On-Demand	NO
HSR	O(n*l)	O(D)	H	Cluster head	Periodic	NO
TBRPF	O(N)	O(D)	F	Parent Node	Periodic and On-Demand	YES
FSR	O(N)	O(D)	F	NO	Periodic	NO
LANMAR	O(N)	O(D)	H	Landmark	Periodic	NO
OLSR	O(N)	O(D)	F	NO	Periodic	YES
HOLSR	O(N)	O(D)	H	Cluster head	Periodic	YES

WCC: Worst Case Complexity (No of messages needed to perform an update operation in worst case); WTC: Worst Case Time Complexity (No of steps involved to perform an update operation in worst case); RS: Routing Structure; F: Flat; H: Hierarchical; HM: HELLO Messages; N: No of nodes in the network; D: Diameter of the network; H: Height of routing tree; N: Average no of nodes in a cluster; L: No of hierarchical levels.

V. FUTURESCOPE AND CONCLUSION

The emphasis in this paper is concentrated on the behavioral study of various pro-active routing protocols and their comparisons. The study will be helpful in identifying which pro-active protocol is best suitable for MANET and how the performance of that protocol can be further improved. Therefore, the study will be of great interest to researchers in getting an idea about which protocol to consider under which circumstances.

REFERENCES

[1] Kaliyaperumal Karthikeyan, Sreedhar Appalabatla, Mungamuru Nirmala and Teklay Tesfazghi, "Comparative Analysis of Non-Uniform Unicast Routing Protocols for Mobile Adhoc Networks", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 12, December 2012.

[2] Santanu Santra and Pinaki Pratim Acharjya, "Comparative Study of Proactive Routing Protocols for MANETs", International Journal of Electronics and Computer Science Engineering, 375, Available Online at www.ijecse.org ISSN- 2277-1956.

[3] Basu Dev Shivahare, Charu Wahi and Shalini Shivhare, "Comparison Of Proactive And Reactive Routing Protocols In Mobile Adhoc Network Using Routing Protocol Property", International Journal of Emerging Technology and Advanced Engineering, Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 3, March 2012).

[4] Kavita Pandey And Abhishek Swaroop, "A Comprehensive Performance Analysis of Proactive, Reactive and Hybrid MANETs Routing Protocols", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 6, No 3, November 2011, ISSN (Online): 1694-0814, www.IJCSI.org

[5] Hemanth Narra, Yufei Cheng, Egemen K. Cetinkaya, Justin P. Rohrer and James P.G Sterbenz, "Destination Sequenced Distance Vector (DSDV) Routing Protocol Implementation in ns-3".

[6] Sachin Kumar Gupta & R. K. Saket, "PERFORMANCE METRIC COMPARISON OF AODV AND DSDV ROUTING PROTOCOLS IN MANETs USING NS-2", IJRRAS 7 (3) June 2011.

[7] Khaleel Ur Rahman Khan, Rafi U Zaman and A. Venugopal Reddy, "The Performance of the Extended DSDV (eDSDV) MANET Routing Protocol and its Suitability in Integrated Internet-MANET", K R KHAN et al: THE PERFORMANCE OF THE EXTENDED DSDV (EDSDV) MANET ROUTING.

[8] Amandeep Makkar, Bharat Bhushan, Shelja, and Sunil Taneja, "Behavioral Study of MANET Routing Protocols", International Journal of Innovation, Management and Technology, Vol. 2, No. 3, June 2011.

[9] Shaiful Alam Chowdhury, Md. Ashraf Uddin and Shahid Al Noor, "A Survey on Routing Protocols and Simulation Analysis of WRP, DSR and AODV in Wireless Sensor

Networks", International Journal of Machine Learning and Computing, Vol. 2, No. 4, August 2012.

[10] Shree Murthy and J.J. Garcia-Luna-Aceves, "An Efficient Routing Protocol for Wireless Networks", Baltzer Journals.

[11] Kae Won Choi, Wha Sook Jeon, and Dong Geun Jeong, "Efficient Load-Aware Routing Scheme for Wireless Mesh Networks," IEEE Transactions on Mobile Computing, Vol. 9, No. 9, September 2010.

[12] S. Senthilkumar and B. Ananthampillai, "A comparative survey of routing protocols in mobile ad hoc networks", Elixir Comp. Sci. & Engg. 37A (2011) 4106-4108.

[13] G.Vijaya Kumar, Y.Vasudeva Reddyr and Dr.M.Nagendra, "Current Research Work on Routing Protocols for MANET: A Literature Survey", G.Vijaya Kumar et. al. / (IJCSE) International Journal on Computer Science and Engineering, Vol. 02, No. 03, 2010, 706-713

[14] CHEN Jing, CUI Guo Hua and HONG Liang, "A Secure Global State Routing for Mobile Ad Hoc Networks".

[15] Tsu-Wei Chen and Mario Gerla, "Global State Routing: A New Routing Scheme for Ad-hoc Wireless Networks".

[16] Stefano Basagni, Irnrich Chlamtac, Violet R. Syrotiuk and Barry A. Woodward, "A Distance Routing Effect Algorithm for Mobility (DREAM)".

[17] M. Bakhouya, J. Gaber, and M. Wack, "Performance Evaluation of DREAM Protocol for Inter-vehicle Communication", GSEM/SeT Laboratory, UTBM 90010 Belfort, France.

[18] Manoj Kumar Singh, Anil Kumar Singh, Brajesh Kumar," Survey and Analysis of DREAM Protocol in the Vehicular Ad-Hoc Network", MIT International Journal of Computer Science & Information Technology, Vol. 2, No. 2, Aug. 2012, pp. (80-84) ISSN No. 2230-7621 © MIT Publications.

[19] Amrit Suman, Ashok Kumar Nagar, Sweta Jain and Praneet Saurav, "Simulation Analysis of STAR, DSR and ZRP in Presence of Misbehaving Nodes in MANET".

[20] Harish Shakywar, Sanjeev Sharma and Santoh Sahu, "Performance Analysis of DYMO, LANMAR, STAR Routing Protocols for Grid Placement model with varying Network Size", Harish Shakywar et al, Int. J. Comp. Tech. Appl., Vol 2 (6), 1755-1760.

[21] Rani Astya, and S.C. Sharma, "Traffic Load Based Performance Analysis of DSR & STAR Routing Protocol", World Academy of Science, Engineering and Technology 56 2011.

[22] Guangyu Pei, Mario Gerla, Xiaoyan Hong and Ching-Chuan Chiang, "AWireless Hierarchical Routing Protocol with Group Mobility", {pei, gerla, hxy, ccchiang@cs.ucla.edu}

[23] Sarosh Patel, Syed Rizvi and Khaled Elleithy, "Hierarchically Segmented Routing (HSR) Protocol for MANET".

[24] V.Umadevi Chezhian, Kaliyaperumal Karthikeyan and Thanappan Subash, "Comparison of Two Proactive Protocols: OLSR and TBRPF using the RNS (Relay Node Set) Framework", International Journal of Computer Science & Emerging Technologies (E-ISSN: 2044-6004) 324, Volume 2, Issue 2, April 2011.

[25] Bhargav Bellur and Richard G. Ogier, "A Reliable, Efficient Topology Broadcast Protocol for Dynamic Networks".

[26] Guangyu Pei, Mario Gerla and Tsu-Wei Chen, "Fisheye State Routing in Mobile Ad Hoc Networks".

[27] Kaixin Xu, Xiaoyan Hong, Mario Gerla, Henry Ly, Daniel Lihui Gu, "LANDMARK ROUTING IN LARGE WIRELESS BATTLEFIELD NETWORKS USING UAVS".

[28] Guangyu Pei, Mario Gerla and Xiaoyan Hong, "LANMAR: Landmark Routing for Large Scale Wireless Ad Hoc Networks with Group Mobility", fpei,gerla,hxyg@cs.ucla.edu.

[29] Yeng-Zhong Lee, Jason Chen and Xiaoyan Hong, "Experimental Evaluation of LANMAR, a Scalable Ad-Hoc Routing Protocol".

[30] Pore Ghee Lye and John C. McEachen, "A Comparison of Optimized Link State Routing with Traditional Ad-hoc Routing Protocols", University of Nebraska–Lincoln DigitalCommons@University of Nebraska – Lincoln.

[31] Thomas Heide Clausen, Gitte Hansen, Lars Christensen and Gerd Behrmann, "The Optimized Link State Routing Protocol Evaluation through Experiments and Simulation".

[32] IMPLEMENTATION of The Optimized Link State Routing protocol, olsr.org.

[33] Gimer Cervera, "Security Issues in Hierarchical OLSR networks", 4th Canada-France MITACS Workshop on Foundations & Practice of Security, Paris, France, May 12-13, 2011.

[34] Gimer Cervera, Michel Barbeau, Joaquin Garcia-Alfaro, and Evangelos Kranakis, "Preventing the Cluster Formation Attack Against the Hierarchical OLSR Protocol", published in "Lecture notes in computer science 6888, 1 (2012) 118-13.