

# *Analysis of Ad Hoc Routing Protocols for emergency and rescue scenarios*

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**Abstract:** A mobile ad hoc network MANET is a collection of wireless mobile nodes that can dynamically configure a network without a fixed infrastructure or centralized administration. This makes it ideal for emergency and rescue scenarios where information sharing is essential and should occur as soon as possible. This article discusses which of the routing strategies for mobile ad hoc networks: proactive, reactive and hierarchical, have a better performance in such scenarios. Using a real urban area being set for the emergency and rescue scenario, we calculate the density of nodes and the mobility model needed for validation. The NS2 simulator has been used in our study. We also show that the hierarchical routing strategies are better suited for this type of scenarios.

## **1 INTRODUCTION**

Mobile Ad Hoc Networks(MANET), are self configuring and temporary networks . Their nodes can be the source, destination and bridge information. They have finite resources (bandwidth, battery, processing) that should be well used with the aim of improving the performance of the entire network.

Continuous improvement of the hardware for end-user equipment (mobile and phones) of wireless network technologies helps to accelerate transmission speed. The emergence of new applications have enabled more users to use smart devices. The nodes in the MANET network work using a set of elements denoted scenario. A scenario is composed of a number of nodes, topography and the definition of mobility algorithm, which includes: direction, speed and pauses of the nodes.

In case of emergency and rescue scenario, the topography is different in the amount of obstacles that may arise due to the occurrence of a undesired events causing the normal mobility pathways to alter. Therefore, the algorithm of motion is determined according to the topography, and the corresponding nodes must be moved depending on the obstacles. The number of nodes depends if the MANET network is in an urban or in a rural area.

When an unwanted event has occurred, it changes the

pathways of normal mobility. Therefore new routes for evacuation and or rescue should be calculated.

When MANET are used in emergency and rescue scenarios, the choice of robust network protocol is essential, because it involves indirect integrity of the person using the mobile device. If a device is not reachable by the network, the events of personal search and rescue should be desconnected from the device.

The main objective of this paper is to determine wich one of the ad hoc routing strategies proactive, reactive and hierarchical performs better in emergency and rescue operations. For this reason we have chosen an area of the city of Loja Ecuador to simulate these protocols supported by the NS2 tool.

## **2 RELATED WORK**

### **2.1 Routing protocols for mobile Ad Hoc networks**

The network layer (Ali et al., 2008), with respect to the OSI reference model, is where one performs and identifies the processes of ad hoc networks. Therefore, any improvement effort in this layer is directly visible in the upper layers.

The routing protocols of ad hoc networks are generally grouped into proactive, reactive and hierarchical routing (Overview and Selangor, 2007).

## 2.2 Proactive routing

Proactive routing protocols maintain information on all routes throughout the network even if they are not required so each node maintains routes to all nodes in the network. These protocols exchange control information between nodes on a regular basis which keeps updated routes for each node in the network. These protocols react when a new node appears or another node, is no longer within the network topology. The known protocols are: Destination-Sequence Distance-Vector DSDV (Perkins and Bhagwat, 1994) and Optimized Link State Routing OLSR (rfc3626).

The idea of proactive routing is to distribute the information periodically through the network in order to pre-calculate all possible paths. When a change occurs in the network, updates are propagated through the network to keep routing tables updated. Therefore, it is an ongoing assessment of the routes between nodes. However, it can cause overloading of the network, affecting the utilization of bandwidth, performance and energy use. In a static topology this routing scheme can work properly. However, in large and highly dynamic networks, non-management has a good scalability.

### 2.2.1 Reactive routing

Reactive routing protocols allow updating of the tables on demand, for example, when a node wants to exchange information with another node in the network. They usually have two components: route discovery, which occurs when a node wants to communicate with a specific destination and route maintenance, used to manage the path failure caused by the mobility of the nodes.

The route discovery ends when we discover the path to the destination node or when all alternatives have been sought without finding any route. The difficulty with these protocols is the latency to initiate communications, they also have a slower reaction to detect changes in the network topology. Among the best known protocols are the Dynamic Source Routing (DSR rfc4728) and Ad Hoc Demand Distance Vector AODV (Perkins et al., 2003).

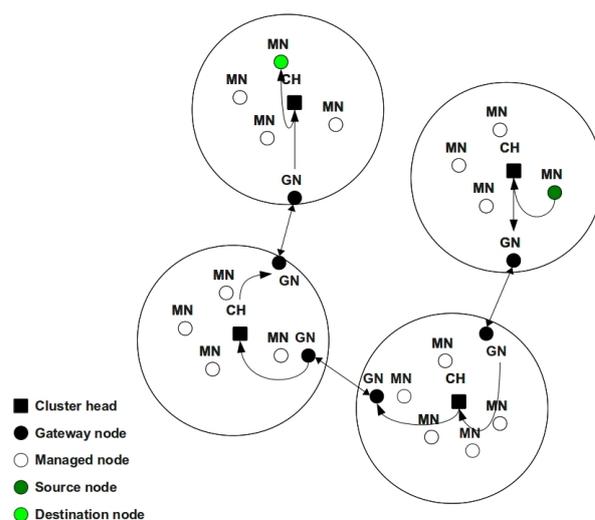


Figure 1: Clustered ad hoc network

This type of routing is based on obtaining routes between nodes, evaluating them whenever necessary. When a node needs to find a route to a destination node, it must initiate a route discovery process. Once the route is adequate, it is maintained until the destination becomes inaccessible or path is no longer required. This limits the total number of destinations to which routing information is maintained and therefore reduces the size of routing tables. However, in this scheme, the quality of the routes is lower compared to proactive routing because there is a significant delay in the route discovery process.

### 2.2.2 Hierarchical routing

Hierarchical routing protocols divide the network into subsets of nodes called clusters, where a cluster head node is used to concentrate and distribute the information generated within the cluster. An example of this type of protocol is the Cluster Based Routing Protocol (CBRP) (Jiang et al., 1999). Figure 1 shows the basic components of a hierarchical routing protocol or cluster.

There are some studies (y Mahesh Motwani, 2009; Biradar and Patil, 2006), that identify and group the hierarchical routing algorithms or clustering. These protocols and hierarchical routing strategies focus on the task of choosing the cluster head and cluster maintenance. For example, (Er and Seah, 2004a; Er and Seah, 2005); focus on the choice of cluster based solely on the property of the node mobility. In turn, (Jiang et al., 1999; Gerla

and chieh Tsai, 1995; Amis et al., 2000); perform cluster head election used as the deciding factor node identification. (Chen et al., 2002) uses the distance between nodes or the degree of connectivity for the election.(McDonald and Znati, 1999) makes the choice of cluster head periodically in order to save energy. The protocols proposed in (Er and Seah, 2004b; Basagni et al., 2001; Chatterjee et al., 2001) made the choice of cluster head based on the combined weights of the characteristics of each node.

### 2.3 Mobility models for mobile ad hoc networks

Mobility models are important because they determine the behavior of mobile nodes (MN) on stage (Camp et al., 2002). They can be classified into two types: those based on traces (logs of actual movements) [14] and the synthetic (emulate reality by mathematical equations). Some authors classify mobility models into three groups (Camp et al., 2002): models based on strokes (work with real mobility), models based on topology restrictions (real scenario simulations) and statistical models (study from randomness).

Ad hoc networks do not work yet on models based on traces on the network characteristics. However, it is expected that study will expand in future on the application of these models (Camp et al., 2002). Therefore, models of synthetic mobility are used together with simulated scenarios. In order to prove this form of controlled mobility, certain parameters are used, which allow to obtain quantifiable data and thus to transform them into useful informaties.

The synthetic models are classified according to their relationship with the representation of human mobility: synthetic mobility models unrealistic, for example: random models (Divecha et al., ) (Random Walk Mobility Model, Random Waypoint Mobility Model), temporal dependency models (Hong et al., 1999; Divecha et al., ) (Boundless Simulation Area Mobility Model, Gauss-Markov Mobility Model, Smooth Random Mobility Model) and realistic synthetic mobility models such as: spatial dependence models (Hong et al., 1999; Chenchen et al., 2010; Chenchen et al., 2010)(Reference Point Group Mobility Model, Column Mobility Model, Pursue Mobility Model, Nomadic Mobility Model) Geographic Restriction Models (Chenchen et al., 2010; Aschenbruck et al., 2008) (Pathway Models, Obstacle Models, Hu-



Figure 2: Action area over Loja city map

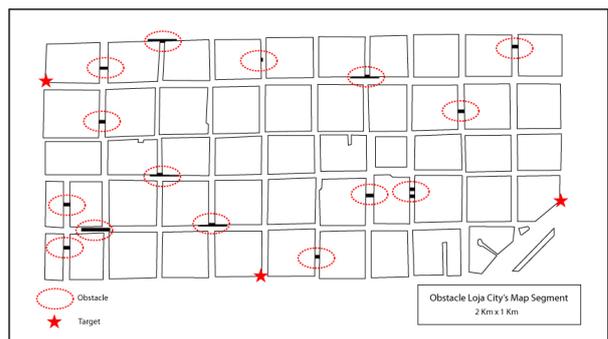


Figure 3: Loja city map without obstacles

man Obstacle Mobility Model).

## 3 PROPOSED SCENARIO

### 3.1 Emergency and Rescue Scenario for centre of the city of Loja

In order set the scene for emergency and rescue, Figure 2, the area of 1000m x 500m of the city Loja is used in Ecuador. The participants urban parishes of the city are: Valley, San Sebastian, Tabernacle and Sucre.

Random obstacles have been defined in this area, Figure 3, that disrupt normal mobility pathways of the nodes.

### 3.2 Node density

The calculation of the node density  $P_{node}$  is supported by information obtained from the census of

Ecuador in 2010.<sup>1</sup> An important factor for the calculation of the nodes is the percentage of the PEA (Economically Active Population).

To calculate the density of nodes the following formula has been proposed:

$$P_{nodes} = \frac{z_{u1} * F_{uel} * F_{PEA} * F_{us}}{A_{zu}} * A_s \quad (1)$$

$$P_{nodes} = 97 \quad (2)$$

Where:

- $z_{u1}$  - Number of people in the urban areas is 70% (128910)
- $z_{r1}$  - Number of people in the rural areas is 30% (85940).
- $F_{uel}$  - urban factor specified for the simulation area
- $A_{zu}$  - Urban area - 6Km x 12Km = 72Km<sup>2</sup>.
- $F_{PEA}$  - LOJA - PEA is 62% for urban area.
- $F_{us}$  - urban smartphone factor is 25% .
- $A_s$  - Chosen area for simulation 0.5km<sup>2</sup>.

It is important to describe the city of Loja for which this study has been done, it is a city in the southern part of Ecuador. Population in the city increases during the holidays, and it grows also due to arriving of tourists attracted by its location and biodiversity. Given this premise, we established percentages of 25.75% ( $F_{us}$ ) and 30.8% ( $F_{us}$ ) to calculate the other two densities nodes  $P_{nodes}$ , substituting these values into the formula(1) we find that the resulting nodes are equal to 100 (25.75%) and 120 (30.8%), respectively.

Consequently the number of nodes for the simulation is: 97, 100 and 120.

### 3.3 General parameters for simulation

To define the simulation scenarios were used as the basis used in (Kurkowski et al., 2007; ?). The values of each one of these values are shown in the Table 1.

In order to analyze results, some authors have revised set of indicators. For our research we select some particular indicators from (Chenna Reddy and ChandraSekhar Reddy, 2006; S. Corson, 1999) in order to measure behavior of protocols. These indicators are: performance, protocol overhead, packet

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Table 1: General parameters for the simulation of protocols AODV, DSDV and CBRP.

| Parameter                 | Value                               | Observations and related works                                     |
|---------------------------|-------------------------------------|--|
| Simulation area           | 500m x 1000m                        | Area established within the centre of the city of Loja             |
| Mobility model            | Obstacle Models                     | Obstacle models (Chenchen et al., 2010; Aschenbruck et al., 2008)  |
| Number of nodes           | 97,100 and 120                      | To determine the behaviour of protocols for different node density |
| Number of connections     | 20, 40                              | random connections   |
| Time of simulation        | 150                                 | In seconds   |
| Network layer protocols   | CBRP, DSDV and AODV                 | Hierarchical, proactive and reactive protocols                     |
| Transport layer protocols | Transmission control protocol (TCP) | A connection-oriented communication is needed                      |
| Propagation model         | TwoRayGround                        | For flat and unobstructed scenarios.                               |
| Type of antenna           | Omnidirectional                     | Indispensable quality of mobile network nodes                      |

loss, average delay and the variation of the delay or jitter. These indicators are compared with those of the following protocols: CBRP(Jiang et al., 1999), AODV(Perkins et al., 2003) and DSDV(Perkins and Bhagwat, 1994).

## 4 SIMULATION RESULTS

The NS2 simulator (ns, ) is used to determine the protocols behaviour with the data shown in Table 1. In order to determine which is the best protocol, we used the following indicators for comparison:

- Average delay. This is very significant to measure for our purpose because there is a need to send and receive network management information as fast as possible.

In this parameter as shown in Figure 4 to 20 connections with 97 nodes the 3 protocols behaviour optimal according to their characteristics, but 100 and 120 nodes CBRP protocol suffers small delay. Instead with 40 connections as seen in Figure 5 already panorama changes to demonstrate advantage that protocol CBRP regarding proto-

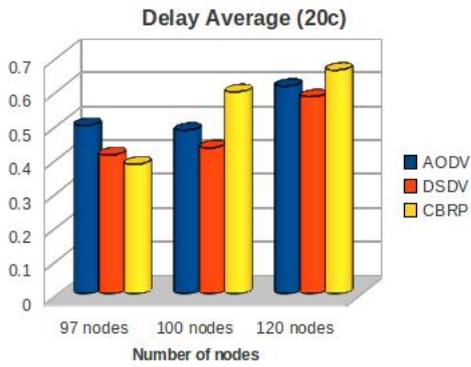


Figure 4: Delay Average - TCP - 20 connections

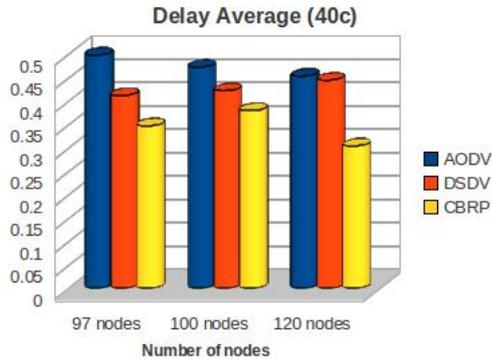


Figure 5: Delay Average - TCP - 40 connections

cols AODV and DSDV. Data in Table 2, Table 3, Table 4.

Table 2: AODV protocols analysis - Delay Average

| Number of nodes | AODV(20c) | AODV(40c) |
|-----------------|-----------|-----------|
| 97              | 0.498009  | 0.498009  |
| 100             | 0.483952  | 0.471993  |
| 120             | 0.613480  | 0.452916  |

Table 3: DSDV protocols analysis - Delay Average

| Number of nodes | DSDV(20c) | DSDV(40c) |
|-----------------|-----------|-----------|
| 97              | 0.411367  | 0.411367  |
| 100             | 0.432102  | 0.421802  |
| 120             | 0.582582  | 0.444208  |

- Packets sent rate - The rate obtained by the number of packets sent to the number of packets received. For the formation and maintenance the cluster needs the exchange of packets to have updated information. As shown in Figure 6 and Figure 7. The protocol that best responds to this parameter is the CBRP protocol for both 20 as for the 40 connections.
- Packet delay variation - It is the difference in de-

Table 4: CBRP protocols analysis - Delay Average

| Number of nodes | CBRP(20c) | CBRP(40c) |
|-----------------|-----------|-----------|
| 97              | 0.383271  | 0.346918  |
| 100             | 0.597227  | 0.379617  |
| 120             | 0.660971  | 0.303840  |

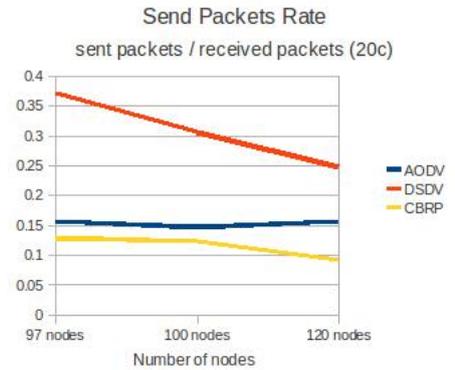


Figure 6: Send Packet Rate 20 connections

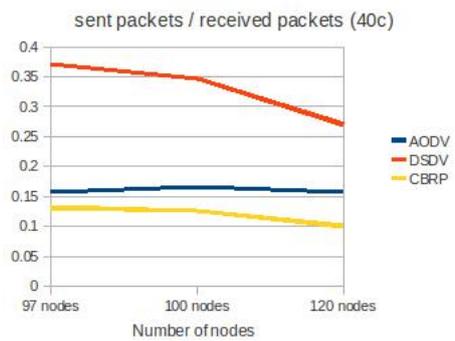


Figure 7: Send Packet Rate 40 connections

lay between communications end-to-end selected packets. It serves to measure the network stability and convergence, in Ad Hoc networks.

This parameter is related to the mean fluctuation and helps us to determine which of the three protocols would be the most appropriate at the time to emergency and rescue. as we can see that this parameter as the two above parameters shows that the protocol is nearest zero consequently has jitter lower the protocol CBRP as seen in Figure 8 and Figure 9. The simulation results are set to Table 5, Table 6, Table 7.

Table 5: AODV protocols analysis - Jitter Average

| Number of nodes | AODV(20c) | AODV(40c) |
|-----------------|-----------|-----------|
| 97              | -0.097499 | -0.097499 |
| 100             | -0.015795 | -0.088908 |
| 120             | -0.009072 | -0.084256 |

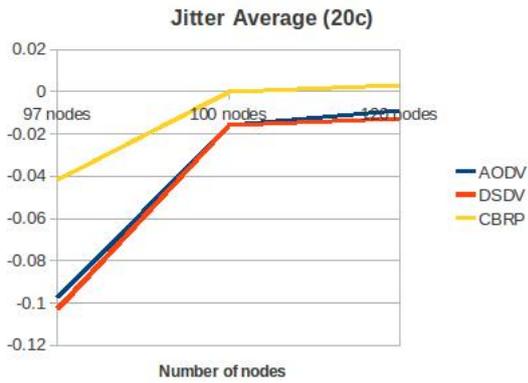


Figure 8: Jitter Average TCP 20 connections

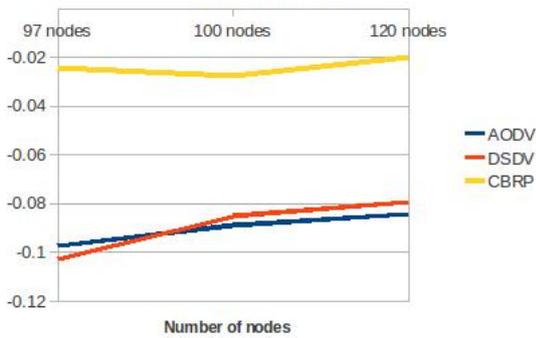


Figure 9: Jitter Average TCP 40 connections

Table 6: DSDV protocols analysis - Jitter Average

| Number of nodes | DSDV(20c) | DSDV(40c) |
|-----------------|-----------|-----------|
| 97              | -0.102806 | -0.102806 |
| 100             | -0.015821 | -0.085109 |
| 120             | -0.01274  | -0.079349 |

Table 7: CBRP protocols analysis - Jitter Average

| Number of nodes | CBRP(20c) | CBRP(40c) |
|-----------------|-----------|-----------|
| 97              | -0.041516 | -0.024319 |
| 100             | -0.000214 | -0.027638 |
| 120             | 0.003136  | -0.019921 |

- Packet Loss - This is the amount of packets dropped by intermediate nodes due to the effects produced by the mobility of these nodes, timer expires, unreachable or erased destination by ARP (Address Resolution Protocol).

The objective of the simulation was to determine which of these three protocols behave better in emergency and rescue scenarios and how we can see in Figure 10 Figure 11 CBRP protocol clears least packets with 20 connections and even better with 40 connections. The data are shown in Table 8 y Table 9.

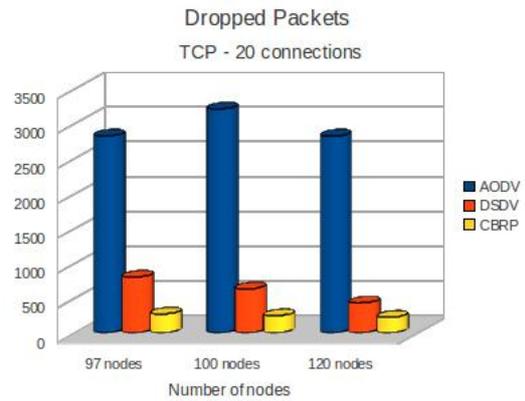


Figure 10: Dropped packets - 20 connections

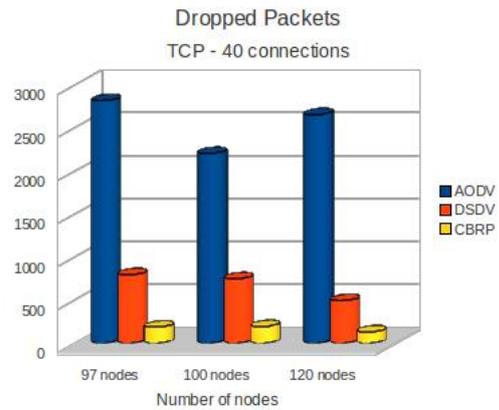


Figure 11: Dropped packets - 40 connections

Table 8: Dropped Packets - 20 connections

| Number of nodes | AODV(20c) | DSDV(20c) | CBRP(20c) |
|-----------------|-----------|-----------|-----------|
| 97              | 2820      | 799       | 269       |
| 100             | 3207      | 631       | 245       |
| 120             | 2819      | 429       | 222       |

Table 9: Dropped Packets - 40 connections

| Number of nodes | AODV(40c) | DSDV(40c) | CBRP(40c) |
|-----------------|-----------|-----------|-----------|
| 97              | 2820      | 799       | 187       |
| 100             | 2206      | 751       | 196       |
| 120             | 2659      | 496       | 133       |

## 5 CONCLUSIONS

- Traditional routing algorithms cannot satisfy requirements of an ad hoc networks, because of

topology dynamics and limited bandwidth characterizing these networks. Consequently, there are a lot of investigations related to existing routing algorithms and there is a discovery of new routing algorithms, which are more efficient.

- This study evaluates and compares CBRP, AODV and DSDV for emergency and rescue scenarios. The experimental results show that the best protocol is CBRP that loses only a few packets for routing, where the sending and receiving rate of packets is stable. The mean fluctuation and the delay is much smaller in relation to the other two protocols. This would support determining that using the protocol CBRP people in a disaster area could be evacuated more efficiently, support points as would be placed promptly.

## REFERENCES

- Ali, N. Z., Ahmad, R. B., and Aljunid, S. A. (2008). Link Availability Estimation for Routing Metrics in MANETs : An Overview. *Time*, pages 6–8.
- Amis, A., Prakash, R., Vuong, T., and Huynh, D. (2000). Max-min d-cluster formation in wireless ad hoc networks. In *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, volume 1, pages 32–41 vol.1.
- Aschenbruck, N., Gerhards-Padilla, E., and Martini, P. (2008). A survey on mobility models for performance analysis in tactical mobile networks.
- Basagni, S., Turgut, D., and Das, S. (2001). Mobility-adaptive protocols for managing large ad hoc networks. In *Communications, 2001. ICC 2001. IEEE International Conference on*, volume 5, pages 1539–1543 vol.5.
- Biradar, R. and Patil, V. (2006). Classification and comparison of routing techniques in wireless ad hoc networks. In *Ad Hoc and Ubiquitous Computing, 2006. ISAUHC '06. International Symposium on*, pages 7–12.
- Camp, T., Boleng, J., and Davies, V. (2002). A survey of mobility models for ad hoc network research. *Wireless Communications and Mobile Computing. Special issue on Mobile Ad Hoc Networking. Research, Trends and Applications*, 2:483–502.
- Chatterjee, M., Das, S. K., and Turgut, D. (2001). Wca: A weighted clustering algorithm for mobile ad hoc networks.
- Chen, G., Nocetti, F., Gonzalez, J., and Stojmenovic, I. (2002). Connectivity based k-hop clustering in wireless networks. In *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on*, pages 2450–2459.
- Chenchen, Y., Xiaohong, L., and Dafang, Z. (2010). An obstacle avoidance mobility model. In *Intelligent Computing and Intelligent Systems (ICIS), 2010 IEEE International Conference on*, volume 3, pages 130–134.
- Chenna Reddy, P. and ChandraSekhar Reddy, P. (2006). Performance analysis of adhoc network routing protocols. In *Ad Hoc and Ubiquitous Computing, 2006. ISAUHC '06. International Symposium on*, pages 186–187.
- Divecha, B., Abraham, A., Grosan, C., and Sanyal, S. Impact of node mobility on manet routing protocols models.
- Er, I. and Seah, W. (2004a). Mobility-based d-hop clustering algorithm for mobile ad hoc networks. In *Wireless Communications and Networking Conference, 2004. WCNC. 2004 IEEE*, volume 4, pages 2359–2364 Vol.4.
- Er, I. and Seah, W. (2004b). Mobility-based d-hop clustering algorithm for mobile ad hoc networks. In *Wireless Communications and Networking Conference, 2004. WCNC. 2004 IEEE*, volume 4, pages 2359–2364 Vol.4.
- Er, I. and Seah, W. (2005). Clustering overhead and convergence time analysis of the mobility-based multi-hop clustering algorithm for mobile ad hoc networks. In *Parallel and Distributed Systems, 2005. Proceedings. 11th International Conference on*, volume 2, pages 130–134.
- Gerla, M. and chieh Tsai, J. T. (1995). Multicluster, mobile, multimedia radio network. *Journal of Wireless Networks*, 1:255–265.
- Hong, X., Gerla, M., Pei, G., and Chiang, C.-C. (1999). A group mobility model for ad hoc wireless networks. In *Proceedings of the 2nd ACM international workshop on Modeling, analysis and simulation of wireless and mobile systems, MSWiM '99*, pages 53–60, New York, NY, USA. ACM.
- Jiang, M., Li, J., and Tay, Y. C. (1999). Cluster based routing protocol (cbrr) functional specification, internet draft, manet working group.
- Kurkowski, S., Navidi, W., and Camp, T. (2007). Constructing manet simulation scenarios that meet standards. In *Mobile Adhoc and Sensor Systems, 2007. MASS 2007. IEEE International Conference on*, pages 1–9.
- McDonald, A. and Znati, T. (1999). A mobility-based framework for adaptive clustering in wireless ad hoc networks. *Selected Areas in Communications, IEEE Journal on*, 17(8):1466–1487.
- ns. The Network Simulator NS-2. <http://www.isi.edu/nsnam/ns/>.
- Overview, R.-A. and Selangor, U. P. M. S. (2007). Existing MANET routing protocols and metrics used towards the efficiency and reliability- an overview. Number May, pages 231–236. Ieee.
- Perkins, C., Belding-Royer, E., and Das, S. (2003). Ad hoc on-demand distance vector (aodv) routing. United States. RFC Editor.
- Perkins, C. E. and Bhagwat, P. (1994). Highly dynamic destination-sequenced distance-vector routing (dsv) for mobile computers. pages 234–244.
- S. Corson, J. M. (1999). Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations. RFC 2501 (Standard).

y Mahesh Motwani, R. A. (2009). Survey of clustering algorithms for manet.