Investigation of MANET routing protocols for mobility and scalability

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Abstract - **This paper focuses on performance investigation of reactive and proactive MANET routing protocols, namely AODV, DSR, TORA and OLSR. MANET is a type of Ad Hoc network, and here its functionality is based on 802.11 IEEE standards to communicate in a discrete and disperse environment with no central management [21]. Hence, the main investigation done in this paper is of the discrete feature and routing in MANET. The main issue of MANET is the breakage of link at certain moment and re-generation of link at certain state as it consists of routers which are mobile in nature i.e. are independent to roam in an arbitrary motion. Also, how they react with the change in topology with the random motion of nodes in certain period of time. The paper presents performance comparison of above mentioned protocol in a varying network sizes with increasing area and nodes size.**

Keywords- manet, routing, opnet, simulation, scalability.

I. Introduction and Related Work

MANET routing provides a number of challenges although it is similar to the traditional networks. This is mainly due to the mobility of the nodes where they become more prone to errors than the wired networks. The route between the nodes may disappear and re-appear due to mobility of the nodes, making routing in MANET more complicated compared to a typical wired LAN or ad-hoc network. In MANET routing goal is to find the optimal path by also taking into consideration communication overhead, latency and power by using most of the available hosts to reach the destination in order to reduce failure in transmission. However, a rapid discovery of alternate route in respect to frequent change in structure of the network involving continuous process of disappearing and regeneration of hosts should not affect the uniformity and optimality of routing packets between the nodes available (*Sastry, 2004)*.

The overall routing protocol types responsible for transmission of packets between different mobile hosts in ad-hoc network falls into three broad categories (as in Fig. 1)

There are a number of studies which looked at the evaluation of a number of MANET routing protocols. However, they focused on certain aspects of the simulation. [15] compared DSR and TORA in OPNET where DSR performed better than TORA.

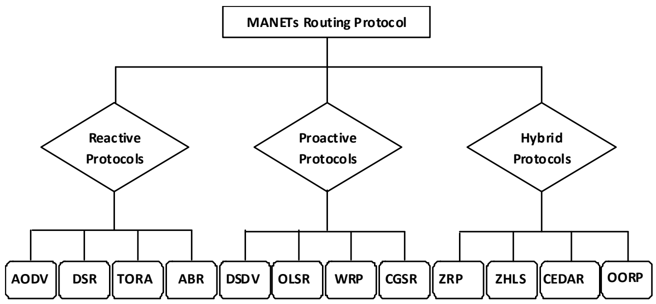

Figure 1. MANET Routing Categories and Protocols

[27] paper evaluated Qos with MANET routing protocols. The paper focused on three main protocols AODV, OLSR and TORA. Their work focused on routing performance with lower network congestion and with fixed number of nodes. They argued that OLSR is the most favourite proactive protocol and AODV is the most effective on-demand protocol within their environment.

[2] also looked into analysing performance of MANET routing protocols. Their study involved comparison of OLSR, DSR and AODV with self similar traffic like CBR, Pareto, and Exponential. They argued that DSR performance was better for packet delivery ratio and OLSR performance degraded in situations where high mobility and network load exist. On the other hand, it was argued that AODV provides the most average performance amongst all.

Similarly, [31] evaluated SPF, EXBF, DSDV, TORA, DSR and AODV with varying number of nodes and looked into scalability of the protocols. However, their study did not look in to employing congestion mechanism and also used simple work load traffic within the network.

On the other hand, the work here focuses on scalability of the protocols by employing heavy congestion with Constant Bit Rate traffic of high load for FTP and video download. Performance of AODV and TORA were found to be equivalent in most of the cases with work of *[31]* and *[2]*.However, the result obtained here is more detailed and have similarities to the work done by *[2]*. They investigated the performance of OLSR and AODV under high Constant Bit Rate traffic. In addition, here results for TORA have been compared to the other protocols as it was done by *[15]*.

II. Simulation Environment and Parameters

The research is carried out using discrete event simulation software known as OPNET (Optimized Network Engineering Tool) Modeler version 14.5. It is one of the most widely used commercial simulators based on Microsoft Windows platform and incorporates more MANET routing parameter as compared to other commercial simulator available. It not only supports MANET routing but also provides a parallel kernel to support the increase in stability and mobility in the network. [35] claims that OPNET's intensive analysing feature provides best environment for comparing and coordinating the output obtained.

The simulation focussed on the performance of routing protocols with increased in scalability and mobility. Therefore, two simulation scenarios consisting of 30 nodes initially and doubling amount nodes i.e. to 60 is considered. The nodes were randomly placed within certain gap from each other in 800 x 800 m and 1500 x 1500 m campus environment for 30 and 60 nodes respectively. The constant File Transfer Protocol (FTP) and video conferencing traffic was generated in the network explicitly i.e. user defined via Application and Profile Configuration. The transmitters and receivers parameter were configured with defining RX-Group in the network.

Every node in the network was configured to execute AODV, DSR, TORA and OLSR respectively. The simulation time was set to 600s and used Karn's Algorithm to calculate the Transmission Control Protocol (TCP) parameters in the network. In addition to that all the nodes were configured with defined path trajectories for mobility in space within certain time interval.

The simulation parameter configured in this research work is influenced from the related work produced on the same field by different researchers namely, *[27], [15], [1], [31], [34], [3], and [35]*.

A. Wireless Parameters

The Wireless LAN parameters were common to all of the four routing protocols as shown in table 1.

In addition, one more wireless LAN scenario was created with RTS set to 256 as configured in the manual provided by *[1]* in order to minimize the chances of collision in the topology assigning RTS/CTS. This was also used to overcome the hidden node problem [1] and provide an efficient operation of MANETs. The same wireless LAN parameters were configured with change in RTS threshold value from none to 256 for second scenario in both 30 and 60 nodes topology.

Table I. Wireless LAN Parameters

Wireless LAN MAC Address	Auto Assigned
BSS Identifier	Auto Assigned
Physical Characteristics	Direct Sequence
Data Rate (bps)	11 Mbps
Channel Settings	Auto Assigned
Transmit Power	0.030
RTS Threshold	None
Packet-Reception Threshold	-95
Short Retry Limit	7
Long Retry Limit	4
AP Beacon Interval (seconds)	0.02
Max Receive Lifetime (seconds)	0.5
Buffer Size (bits)	102400000
Large Packet Processing	Fragment
HCF	Promoted

The wireless LAN parameters configured matches to research work of *[27]*, except the buffer size was set to 102400000 bits as heavier flow of application was generated. In addition, the channel settings were set to "auto assigned" in order to avoid manual error. Also the transmission power was changed from 0.005 watt to 0.030 watt.

B. Traffic Flow Parameters

Traffic was generated in the network explicitly by configuring user defined application and profile definition.

1) Application Configuration

A heavier application traffic flow in the topology was generated which each node will be processing from the respective application server in the network. The application traffic generated was as, FTP_Application: High Load and Video Conferencing: High Resolution Video.

Table II. FTP Application Parameters

FTP Application Parameters	
Attribute	**Value**
Command Mix (Get/Total)	0%
Inter-Request Time (seconds)	Constant (3600)
File Size (bytes)	Constant (15000000)
Symbolic Server Name	FTP Server
Type of Service	Best Effort (0)
RSVP Parameters	None
Back-End Custom Application	Not Used

The traffic generation parameter used for FTP_Application are the same as in the manual provided by *[1]*, also in addition to that to allow more traffic flow in the network video application was also configured with default values available in OPNET for higher resolution video.

2) Profile Configuration

The profile configuration for each application was defined as, Operation Mode: Serial (Ordered) and Start Time: 55 Seconds. In addition, the FTP application start time was set to constant 5 seconds of time period as similar to those configured in the manual provided by *[1]* and the video application start time was set at constant 75 seconds. The constant mode of application traffic was selected so as to generate Constant Bit Rate (CBR) traffic flow in the network.

C. Routing Protocol Parameters

The configuration parameter for AODV was setup as in the work of *[27]* except Time-To -Live (TTL) was set to default configuration as set by OPNET Modeler 14.5. The gratuitous reply was enabled for AODV as it helps in reducing the time for route discovery. Also, the "hello" interval time was increased in AODV parameter from the default value to decrease the congestion in the topology

[27]. The configuration parameter used for DSR was similar to work done by [34].

Table III. AODV Parameters

Route Request Retry	5
Route Request Rate Limits (pkts/sec)	10
Gratuitous Route Reply Flag	Enabled
Active Route Timeout (seconds)	30
Hello Interval (seconds)	Uniform (10, 10.1)
Allowed Hello Loss	10
Timeout Buffer	2

Table IV. DSR Parameters

Time Between Retransmitted Request	500 ms
Size of Source Route Header Carrying n Addresses	4n + 4 bytes
Timeout For Non-propagating Search	30 ms
Time to Hold Packets Awaiting Routes	30s
Maximum Rate for Request Sending Replies for a Route	1/sec

The TORA and OLSR parameter that I have set were similar to those in work produced by *[27]*. The parameter of willingness is changed to 'always' from the default value so as to decrease the MPR's in the network because MPR nodes generate periodic Topological Control (TC) message in the network and the increase in MPR nodes means generation of the more number of TC message in the network.

Table V. TORA and IMEP Parameters

Beacon Periods	3secs
Max Beacon Timer	9secs
Max Tries	3 attempts

D. *RX Configuration Parameter*

All the RX configuration in the network was set to default except for the node refresh time was set to every 10 seconds periodic interval.

Table VI. OLSR Parameters

Willingness	Willingness Always
Hello Interval (seconds)	2.0
TC Interval (seconds)	5.0
Neighbour Hold Time (seconds)	6.0
Topology Hold Time (seconds)	15.0
Duplicate Message Hold Time (seconds)	30.0
Addressing Mode	IPv4

E. *Trajectory Configuration*

All nodes were configured to move in a path defined in the 'trajectory1_AS' parameter. The detail of the 'trajectory1_AS' is shown in the figure below. The trajectory configuration was similar to those in the manual provided by *[1]*. The trajectory basically defines the path for nodes to move in space in given periodic interval of time. In my simulation the mobile nodes wait until 120 seconds and start moving in the path direction as defined in the trajectory parameter.

F. *DES Configuration Parameter*

The DES simulation criterion was configured as similar to the manual provided by *[1]* and was run for total time of 600 seconds. The overall simulation was monitored within the following criteria:

- Duration: 10 minutes (600 seconds)
- Seed: 256
- Update Interval: 500000 events. (This specifies how often simulation calculates events/second data.)
- Simulation Kernel: Optimized ('Optimized' kernel was chosen because it runs faster than the remaining other two simulation kernel.)

III. RESULTS AND ANALYSIS

The work attempts to compare the protocols in two scenarios i.e. with RTS 0 and 256 respectively for all performance metrics considered.

A. *Wireless LAN Delay*

Fig. 2 shows that the overall delay in the network, AODV has the highest LAN delay marked at the scale of 28 and 25 seconds for 0 and 256 RTS value respectively. This is because AODV does not keep routing information as other on-demand protocols, instead it uses of Destination sequence number together with different identifiers for routing between the nodes in topology. The route configured by the AODV have short lifespan, therefore periodic update has to be completed which compels route expiry. In addition, the re-initialisation of route discovery at certain intervals, results in higher delay to be observed. Furthermore, link failure detection is not quick enough, which results in sending the packets through the failed nodes.

OLSR results in much less delay as compared to AODV with the average delay marked at 8 and 6 seconds respectively for '0' and '256' RTS value. This is because OLSR uses MPR set and MPR selector set. However, increased in size of MPR set decreases the efficiency of protocol *[23]*. On the other hand, TORA outperforms both AODV and OLSR as it generate less control packets by localising the overhead generated to only certain routing area of the node without affecting the whole network. This ultimately reduces the number of route discovery and re-initialisation packets.

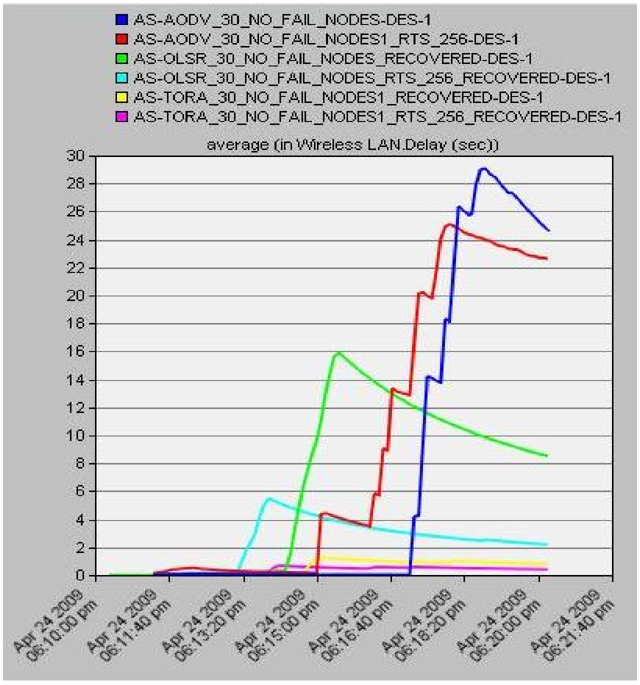

Figure 2. Average in wireless LAN delay (seconds)

B. Routing (Network) Load:

Fig. 3 shows the increase in network load for OLSR. For OLSR the routing load takes the peak at initial stage of the simulation with the drastic rise and drops down slowly as the simulation progresses. This is simply because of the constant mobility of the node; there is a frequent change in the link state and this result in the change in MPR node due to random mobility. This is in turn results in periodic broadcast of ‘hello’ message and Topology Control (TC) messages in order to discover neighbourhood nodes. In addition, OLSR is a link state protocol which uses a table driven approach. Therefore, it generates more communication overhead and takes more maintenance time which adds to the overall load in the network.

AODV on the other hand has higher network load due to the fewer routing information packets kept in its cache. Therefore, the frequent transmission of RREQ and RREP messages results in generation of higher communication overhead. This uses the bandwidth available and increases the routing load within the network. On the other hand, TORA limits the communication overhead to the node area in order to increase the bandwidth utilisation. In addition, due to the link reverse algorithm employed within TORA, link failures are localised to certain area of the topology which in return improves the performance of the network.

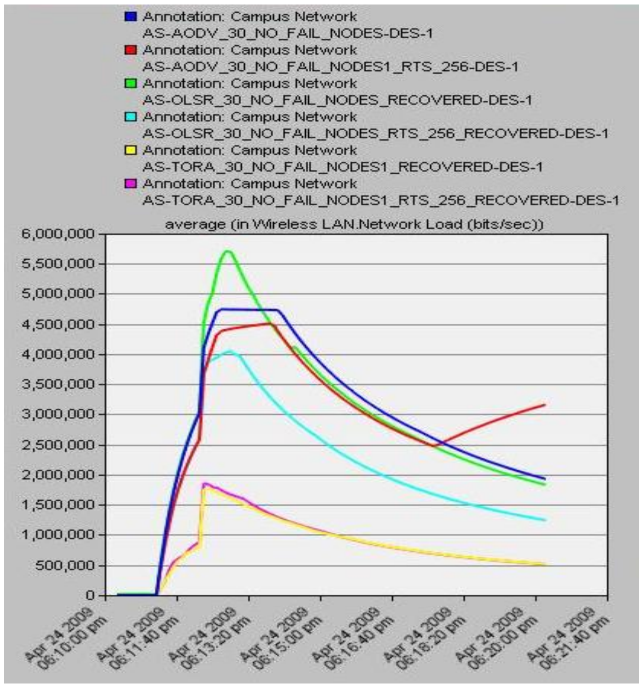

Figure 3. Average in wireless network load (bits/sec).

C. Media Access Delay:

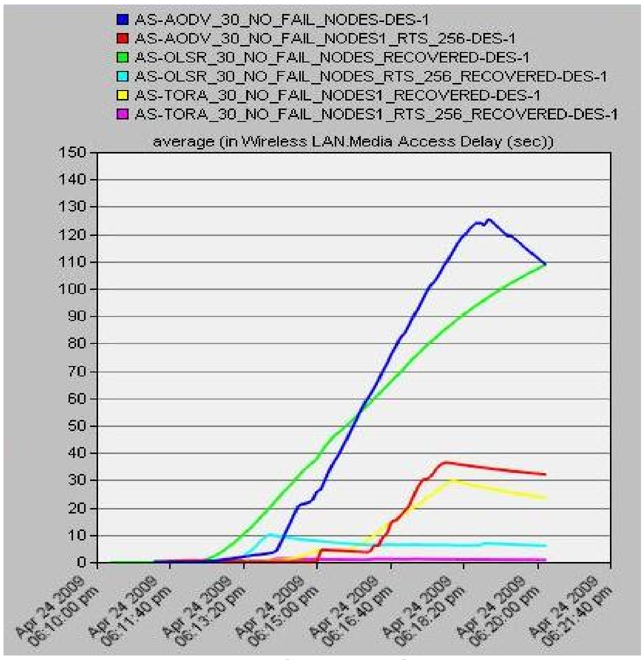

Figure 4. Media Access Delay (sec)

[15] showed that Media access delay was lowest in TORA compared to other proactive protocols. This was due to improved overhead in maintaining the communication between nodes. This feature of TORA is also observed in Fig. 3. TORA has a better media access delay due to the use of Directed Acyclic Graph (DAG) in localising the nodes. On the other hand, OLSR has a better media access delay as it is effectively a Link State algorithm. Overhead is reduced as limited number of links takes part during the updates.

In Fig. 4 AODV shows the worse media access delay due to the process of reinitializing the route flooding process every time while discovering new routes and determining the changes in the topology. AODV broadcasts RREQ messages in order to maintain smaller cache memory.

D. End to End (Segment) Delay:

Fig. 5 shows increase in the segment delay in TORA due to the existence of short temporary loops. This results in packets going round and round in the network until it reaches the limit time to live and they are finally dropped. This formation of temporary loops results in heavy network congestion and creates collision at the lower level. This forms a partition in the network and resulting in higher segment delay in case of TORA. *[32]* argues that, higher end-to-end delay with TORA is caused due to the loss of route information in routing.

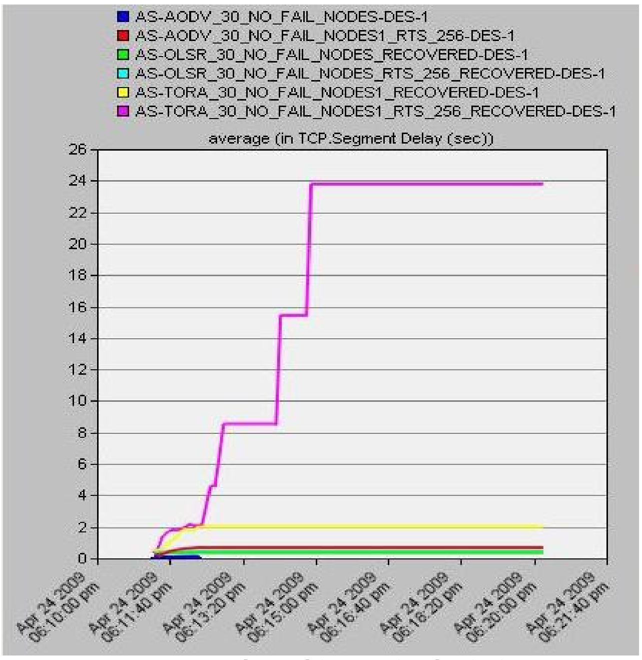

Figure 5. End to End (Segment) Delay (sec)

Fig. 5 shows lower segment delay for AODV and OLSR. For AODV this is due to, frequent broadcasting of RREQ and route re-initialisation messages to find an optimal freshet path. In addition, the use of Destination Sequence Number for every RREQ increases the efficiency of the link without needing to execute the large routing table every time (as in other on-demand protocols). Therefore, the response is quick and convenient between the intermediate nodes once the discovery of route and initialisation process is completed.

OLSR on other hand maintains cluster of nodes in the topology by dividing them into different node sets. Dividing the sets into one hop and two hop neighbours makes OLSR more efficient in link update process without having all nodes taking part in this. In addition, maintaining "Neighbour Table" and keeping track of other nodes available via one and two hop neighbours leads to less end-to-end delay in OLSR. Furthermore, the constant exchange of "hello" and TC messages verify the link state and makes OLSR segments more reliable which results in lower transmission delays.

E. Throughput (bits/sec):

Fig. 6 shows the throughput for each protocol. It is clear that OLSR and AODV has shown increased throughput regardless of the delay and routing load observed during initial routing process. In the figure, OLSR generated higher throughput during the initial and mid stage (600 seconds). It also peaked at 7200000 bits/sec and dropped to a stable level for the rest of the simulation.

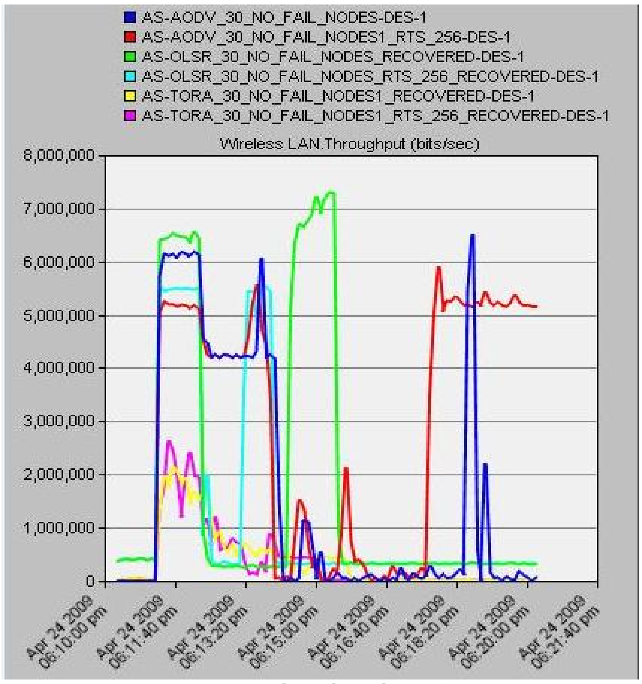

Figure 6. Throughput (bits/sec)

TORA on the other hand performs the worst case although it minimizes the control overhead generation by localising the nodes. This is because, TORA constantly produces unwanted overhead due to its "Route Adaptation" feature (i.e. to update path information and route establishment with change in topology results). The other main factor of lower throughput observed by TORA is because; it deletes all route information when they are not in use *[31]*. This results in generating lower throughputs. On the other hand, availability of multiple route information in AODV and TORA is another great advantage in producing higher throughput in the network.

IV. CONCLUSION

In this paper, performance of AODV, OLSR and TORA was analysed using OPNET modeler 14.5. The protocols were tested using the same parameters with high CBR traffic flow and random mobility. Performance of protocols with respect to scalability has also analysed.

Results showed that, AODV and OLSR experienced higher packet delay and network load compared to TORA. This was due to the localisation mechanism employed in TORA. Similar characteristics were also shown in *[2]*. On the other hand, when segment delay is considered both OLSR and AODV performed very reliably and established quick connection between nodes without any further delay. However, TORA showed high end-to-end delay due to formation of temporary loops within the network. This was verified in the work carried out by *[15]*.

Finally, when overall performance is compared, Throughput was considered as the main factor because it is the actual rate of data received successfully by nodes in comparison to the claimed bandwidth. TORA again performed worst among the three analysed protocols, delivering much lower throughput than AODV and OLSR. It was argued that, this was due to table driven approaches having more complicated routing procedure [14]. With regards to overall performance, AODV and OLSR performed pretty well showing average performance throughout the simulation which is equivalent to result generated by other researchers [ref]. However, AODV showed better efficiency to deal with high congestion and it scaled better by successfully delivering packets over heavily trafficked network compared to OLSR and TORA.

V. Acknowledgements

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VI. References

[1]: Aboelela Emad, Ph. D. "Chapter 15 – Mobile Wireless Networks: Network Simulation Experiments Manual" – 2nd Edition, Morgan Kufman Publishers, 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA. 2008 Elsevier Inc., ISBN : 978-0-12-373974-2

[2]: Al-Maashri, Ahmed and Mohamed Ould-Khaoua, "Performance Analysis of MANET Routing Protocols In Presence Of Self-Similar Traffic" – Dept. of Electrical and Computer Engineering – Sultan Qaboos University, Sultanate of Oman, 2006, IEEE

[3]: Anipakala Suresh, "Performance Analysis of Ad Hoc On-demand Distance Vector Routing (AODV) Using OPTNET Simulator" – University of Bremen – 11th April 2005. Cited on: www.comnets.uni.bremen.de/~koo/OPNET-AODV-asn.pdf

[4]: Beauchamp, K. G.; "Computer communications. - 2nd ed." - Chapman and Hall, 1990. – 0412370700

[5]: Carpenter, Tom; "Wireless Certification Official Study Guide. - (Exam PW0-050)." - Osborne/McGraw-Hill, 2006. – 0072263423

[6]: Changling Liu, Jorg Kaiser (2005); "A survey of Mobile Ad Hoc network Routing Protocols", The University of Magdeburg; the University of Ulm Tech. Report Series, Nr. 2003-08.

[7]: Comer, Douglas; "Computer networks and internets: with Internet applications - 3rd ed.", Prentice Hall, Upper Saddle River, N.J., 2001. – 0130914495

[8]: David Oliver Jorg; " Performance Comparison Of MANET Routing Protocols In Different Network Sizes", Institute of computer Science and Applied Mathematics, Computer Networks and Distributed Systems (RVS), University of Berne, Switzerland, 2003.

[9]: Derfler, Frank J. & Les Freed, "How networks work. - 6th ed." -: Que, Indianapolis, Ind., 2003 – 0789727536

[10]: E. Comer, Douglas; "Computer networks and Internets: with Internet applications - 4th ed.", Prentice Hall Upper Saddle River, N.J.; London:, 2004 . - 013123627x

[11]: Forouzan, Behrouz ; "Data communications and networking - 4th ed.", McGraw-Hill, London 2007 . – 0071254420

[12]: H.T. Vu, M. Thoppian, A. Mehdian, S. Venkatesan, R. Prakash & A. J. Anderson; " Real-time simulations of Mobile Ad-hoc Networks (MANET) in Opnet Modeler" , The university of Texas at Dallas, Richardson, Tx 75083

[13]: Hongbo Zhou (2003), "A Survey on Routing Protocols in MANETs", Department of Computer Science and Engineering, Michigan State University, East Lansing, MI 48824-1027, May 28, 2003.

[14]: Huseyin Arslan, Zhi Ning Chen and Maria-Gabriella Di Benedetoo (eds) – " Chapter 15 – An Overview of Routing Protocols for Mobile Ad Hoc Networks – Ultra Wideband Wireless Communication" – John Wiley and Sons, 2006.

[15]: Kaosar, Md. Golam; Hafizm Asif, Tarek R. Sheltami, Ashrof S. Hasan Mahmoud – "Simulation – Based Comparative Study of on Demand Routing Protocols for MANET." Department of Computer Engineering, King Fahd University of Petroleum and Minerals, Dhahvan 31261, USA.

[16]: Kwan-Wu Chin (2005), "The Behaviour of MANET Routing Protocols in Realistic Environments", copyright- IEEE, Telecommunications Information Technology Research Institute, University of Wollongong, Northfields Ave, NSW, Australia 2522.

[17]: Lajos Hanzo II & Rahim Tafazolli (2007); "ASurvey of QOS Routing Solutions for Mobile Ad Hoc Networks"; IEEE communication Surveys, **2nd Quarter 2007, volume 9,** Number 2.

[18]: Lammle, Todd; "CCNA Cisco Certified Network Associate study guide – 6th ed.", - Hoboken, N.J.: Wiley, 2007. - 0470110082

[19]: Lawrence M. Leemis & Stephen K. Park; "Discrete Event Simulation- A First Course"; -: Pearson Prentice Hall, Pearson Education Inc., Upper Saddle River, NJ 07458; 2006. – 0-13-142917-5

[20]: Loay Abusalah, Ashfaq Khokhar, and Mohsen Guizani-A Survey of Secure Mobile Ad Hoc Routing Protocols, IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 10, NO. 4, FOURTH QUARTER 2008.

[21]: Luc Hogie; pascal Bouvry; Frederic Guinand – "An Overview of MANETs Simulation"; Elsevier B.V.; 2006.

[22]: Mackenzie, Lewis; "Communications and networks." -: McGraw-Hill, London, 1998. – 0077092732

[23]: Murthy, C. Siva Ram; "Ad hoc wireless networks: architectures and protocols." - : Prentice Hall PTR, Upper Saddle River, N.J., 2004. - 013147023x

[24]: Na Wu (1999) QoS-Driven Routing and Resource Scheduling In Wired and Wireless Networks, UMI, Bell & Howell Infonnation and Leaming, 300 Nor1h Zeeb Road, Ann Arbor, MI 48108-1346 USA -800-521-0600

[25]: Odom, Wendell, Tom Knott; "Networking basics CCNA 1 companion" -: Cisco, Indianapolis, Ind., 2006. – 1587131641

[26]: Peterson, Larry L. & Bruce S. Davie; "Computer networks : A systems approach - 3rd ed.", Morgan Kaufmann, San Francisco, Calif.; London 2003

[27]: Qasim Nadia, Said Fatin & Aghvami Hamid – "Mobile Ad Hoc Networking Protocol's Evaluation through Simulation for Quality of Service." - IAENG International Journal of Computer Science, 36:1, IJCS_36_1_10, 17 February, 2009.

[28]: Qin Liang and Kunz Thomas – "Survey on Mobile Ad Hoc Network Routing Protocols and Cross – Layer Design"; Carleton University, Systems and Computer Engineering, Technical Report SCE-04-14, August 2004.

[29]: Raymond R. Panko, "Business Data communications and networking", Prentice Hall, Upper Saddle River, New Jersey, 2001. 0-13-088262-3

[30]: Riley George and Ammar Mostafa. Simulating large networks: How big is big enough? In proceedings of First International Conference on Grand Challemges for Modeling and simulation, January 2002.

[31]: Samir R. Das, Robert Castaneda and Jiangtao Yan; "Simulation – based Performance Evalution of Routing Protocols for Mobile Ad Hoc Networks" Baltzer Science Publishers BV. {*A Preliminary version of this paper appeared in the Seventh International conference on Computer Communication and Networks (IC3N), Lafayette, LA, October 1998.}*

[32]: Sarkar, Subir Kumar, T.G. Basavraju and C. Puttamadappa – "Ad Hoc Mobile Wireless Networks: Principles, Protocols and Applications."; Auerbach Publications,2008.

[33]: Stallings, William; "Data and computer communications - 8th ed." -: Prentice Hall, New Jersey, 2007 – 0132433109

[34]: Tony Larsson, Nicklas Hedman – "Routing Protocols in Wireless Ad-hoc Networks – A Simulation Study" – Lulea University of Technology, Stockholm, 1998.

[35]: Wells Paris, "Ad Hoc Wireless Network Comparision – A Comparision between DSR and AODV Routing Protocols" – Wireless Data Communications System, School of Engineering and Design, Brunel University

[36]: Xinjie Chang; "Network Simulations with OPNET"; Winter Simulation Conference-1999; Network Technology Research Center (School of EEE), Nanyang Technological University, Singapore.

[37]: Zhong Xiaofeng; Wang Youzheng; Mei Shuliang; Wang Jing – "A Stable Adaptive Optimization of DSR Protocol." Springer-Verlag, Berlin, Heidelberg 2003.