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| Missouri university of science & technology |
| MANETs: Optimum Number of OSPF Areas |
| Final Project/Model |
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| **4/22/2012** |

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# 1.0 Introduction

 Mobile Ad hoc Networks (MANETs) are critical for providing the infrastructure for network communication in areas where there is little or no terrestrial network infrastructure. One of the areas where MANETs are evolving is that of the Tactical Internet within the Army’s Warfighter Information Network- Tactical (WIN-T). The Lower Tactical Internet (LTI) which is approximately from the company level down to the dismounted soldier. This project deals with one of the problems in the LTI; it is the Open Shortest Path (OSPF) Network Routing protocol. OSPF is standards based hierarchical link state routing protocol that has been historically used in fixed terrestrial networks’ of internet service providers and large enterprises. OSPF uses a backbone area called area zero and all other areas have to connect directly to area zero. One of the main issues is the number of link state advertisements (lsas) that are generated when a network nodes link looses connectivity from its neighbors in its area. The second issue with using OSPF in MANETs is node movement or mobility. In the LTI there is plenty of mobility by the soldiers on foot and using vehicles. As the mobile nodes move within their areas and outside their areas, link connectivity is lost and created. This activity generates multiple lsas and changes the makeup of the network areas.

 There are numerous studies and research being conducted to address the limitations of OSPF’s use in MANETs. This paper is based on an idea taken from authors Jun et al from North Carolina State University. The title of their work is “The Optimum Number of OSPF Areas for MANETs”. My project consists of trying to duplicate there analytical model and simulations although solutions and code were not available. I anticipate this attempt will leave many open areas of question, but provide problems for follow on research.

 

 Figure small OV of a lower tactical network

Taken from General Dynamic’s website.

# 2.0 Background

 The OSPF for MANETs has been actively investigated for years. There have been several extensions proposed to facilitate use for MANETs. They are flooding backbone, differential hellos, smart peering, and distance effect. Most of that work has been based on the assumption of a single OSPF area. The authors propose using multiple OSPF areas to enhance the scalability for MANETs. They perform a theoretical analysis to show that there are an optimum number of areas that optimize the overhead lsas on the network. The analytical model is verified with detailed simulation experiments. The author provides several base equations, graphs, and conclusions from their simulation work. The authors concluded that by using multiple OSPF areas, they can reduce the lsa overhead as much as 95% as compared to the single area case.

 A single area case would place all the nodes in one logical area zero. That would work fine in a network of a small amount of nodes and within limited communication distance. The LTI could span multiple miles in varied terrain with obstructions. It would take multiple area construction with mobiles that could exceed the normal transmission distance. The authors take several liberties in their approach to the problem. They assume that the communication distance is 250 meters, that the areas are level and perfect squares, and that the terrain is flat. They also assume the network doesn’t have to adhere to the OSPF rule of all areas have to connect to area zero to communicate with other nodes outside their area.

 Random waypoint mobility model has been widely used in modeling of MANETs. A mobile node moves about a continuous plane randomly choosing its destination, speed, pause time, and forward destinations. The node will reach a point, pause for some random time, and then start the process of random movement all over again. The movement of a node from its starting point (waypoint) to its destination (waypoint) with the time it takes as the transition time. The distance the nodes move between the waypoints is the transition length. [2]

 Below is a diagram of how the areas were constructed for purposes of their study.



 Figure node movement in area and outside area

The above diagram part a shows a small network with an area constructed inside the circle. Part b shows how a node might move from one point to another. Part C shows the second part of that movement and movement depiction. The authors’ use a special case of the random waypoint model to represent the notional movement of the nodes. [1]



 Figure node movement in symmetrical areas

[1]

The above figure, section c, shows how a mobile node might travel within its area and into another area. Those two events are examples that would cause lsa flooding due to the change in link state. The author goes on to derive equations for the number of lsas generated.  



[1]



The author comes up with the above equation to show the number of lsas that are generated due to the node mobility.

The author generates the below graphs depicting the number of areas versus lsas and number of nodes. They assume a node density of 20 nodes/km^2. The signal range is 250 meters.



 Figure lsa versus nodes from study

Next they show that the optimum number of areas can be obtained by solving the following quartic equation: , 

Where .

# 3.0 Methodology

First we create a Matlab script to calculate the number of link state advertisements based on the authors’ equations. Next I try and solve the quartic equation presented by the author. The notion is to take the result and write a script to solve and graph the results.

Finally show a random waypoint simulation based on code I found on Mathworks file exchange.

# 4.0 Results and Discussions

 One example the authors use is if the number of nodes= 320, r=250 meters, and l = 1000 meters. The come up with a value for a=8 and A (optimum number of areas) = 64. I created a script a\_quartic.m to verify the calculation. My results were sym a ;

solve('(a^4 + 2\*a^2 + 6\*a -3)/a -500= 0'), with a = 7.8228660544458405294715312813478. It also had complex roots: 6.9191184106055218530046339411633\*i - 3.9083966646291372623393650864511

 - 6.9191184106055218530046339411633\*i - 3.9083966646291372623393650864511 which I assume the authors deemed it safe to throw away. It follows that the number of areas have to be a real value.

 Figure nodes versus optimum number of areas

In figure 5 it can be seen that as the number of nodes increase, the optimum number of areas increase as well.

 Figure nodes versus optimum areas

In figure 6 above the number of ospf areas on the x axis versus the number of lsas on the y axis shows as the nodes increase the lsas increase. At around 280 areas the graph takes a steep increase. This doesn’t take the nice more shallow curve up that were found in the research paper.

 Figure optimum areas versus LSAs

# 5.0 Conclusions

 The results obtained by the authors of the study were a bit tough to obtain. In general my results were in agreement with their findings. As the number of areas increased the number of total link state advertisements increased as well. The authors were able to obtain a leveling in their graphs which indicated the optimum number for the particular number of nodes or lsas. In addition, the software they used to validate their analytical models weren’t obtainable. There is more work that needs to be done on my part to determine why at least my analytical models didn’t more closely follow the authors’ results.

# 6.0 References

1. Jangeun Jun; Sichitiu, M.L.; Flores, H.D.; Eidenbenz, S.J.; "The Optimum Number of OSPF Areas for MANETs," *Sensor, Mesh and Ad Hoc Communications and Networks, 2007. SECON '07. 4th Annual IEEE Communications Society Conference on* , vol., no., pp.451-460, 18-21 June 2007
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URL: <http://ieeexplore.ieee.org.libproxy.mst.edu/stamp/stamp.jsp?tp=&arnumber=4292857&isnumber=4292805>

2. Roy, Radhika Ranjan, “Handbook of Mobile Ad Hoc Networks for Mobility Models” Chapter 4, 2011.

# 7.0 Appendices

Matlab code has been uploaded with the report.

optimum\_areas.m

lsas.m

a\_quartic.m

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| --- | --- | --- | --- | --- |
| nodes | beta | a | A | LSAs |
| 20 | 31.284 | 2.753 | 9 | 16.984 |
| 40 | 62.568 | 3.68 | 16 | 66.8888 |
| 80 | 125.136 | 4.793 | 25 | 267.0316 |
| 160 | 250.272 | 6.148 | 36 | 1.07E+03 |
| 320 | 500.544 | 7.825 | 64 | 4.27E+03 |
| 640 | 1.00E+03 | 9.914 | 100 | 1.71E+04 |
| 1280 | 2.00E+03 | 12.534 | 169 | 6.83E+04 |
| 2560 | 4.00E+03 | 15.824 | 256 | 2.73E+05 |
| 5120 | 8.01E+03 | 19.97 | 400 | 1.09E+06 |

 Figure table of data calculated