Analysis of Local Route Maintenance for Ad Hoc Network*

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Abstract. In ad hoc network, most link ailure recoveries can be localized to a small region along the previous route. However, the theory is not proved by mathematic analysis and simulations. In this paper, we analyze it by mathematical analysis and by simulations.

Keywords: Ad hoc network, Local Route Maintenance, Mathematics Analysis.

1 Introduction

An ad hoc Network [1] is a multi-hop wireless network. According to that most link failure recoveries can be localized to a small region along previous route [2], NSMP [3] and PatchODMRP [4] are proposed to prolong their flooding periods by their local route maintenance. However, none of them mathematically analyze the local route maintenances, and the functions of the local route maintenances are not clearly. Therefore, we analyze local route maintenance by mathematic analysis and simulations in this paper.

2 Local Route Maintenance

NSMP adopts a neighbor supporting local route discovery system to reduce its control overhead. In NSMP, during its forwarding mesh setting up, the nodes, which will transmit data packets, are marked as forwarding nodes, and the nodes, which are neighbors of forwarding nodes, are defined as neighbor nodes. After forwarding mesh has been setup, normal source maintains its forwarding mesh mainly by periodically flooding control packets in the scope of its forwarding nodes and its neighbor nodes.

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PatchODMRP extends ODMRP by its local route maintenance. It sets up its forwarding mesh as ODMRP does. During its transmission of data packets, forwarding nodes know the status of their neighbor nodes by BEACON signal of MAC layer. When a forwarding node finds that a link between its upstream node and itself is broken, it does its local route maintenance in two-hop or three-hop.

3 Mathematic Analysis of Local Route Maintenance

In this section, we analyze the characters of local route maintenance by a random graph. The graph presents an ad hoc network, which is formed by n mobile nodes in a square (1000m×1000m), and each node has n' ($n' \le n$) neighbors.

In ad hoc network, if a link failure is caused by a node failure, then the possibility that the link failure can be amended is equal to the possibility that a i-link path exists between any two un-neighbor nodes.

Statement 1: In ad hoc network, the possibility p_i' that there is only a i ($i > 1$) links path between any two un-neighbor nodes is: $p_i' = \dfrac{(n')^i \times (1 - \frac{n'}{n})^{\frac{i(i-1)}{2}}}{n}$, ($i > 1$).

Proof: In ad hoc network, the possibility that a node is a neighbor of another node is $\dfrac{n'}{n}$. A i ($i > 1$) links path between any two un-neighbor nodes, from a source to a destination, consist of two parts:

1. A $i-1$ links path from the source to one of the neighbors of the destination.
2. A one-link path from the destination to one of its neighbors.

Then, the probability p_i' that only a i-link path exists between any two un-neighbor nodes is a product of the following three fractions:

1. The number of neighbors of the destination.
2. The probability p_{i-1}' that the source reaches one of the neighbors of the destination through a $i-1$ links path.
3. The probability $(1 - \dfrac{n'}{n})^{i-1}$ that the destination is not a neighbor of the first $i-1$ nodes on the $i-1$ links path.

Now, we can know that the probability p_i' that there is a i ($i > 1$) links path between any un-neighbor nodes is:

$$p_i' = p_{i-1}' \times n' \times (1-\frac{n'}{n})^{i-1} = n'^{\,i-1} \times (1-\frac{n'}{n})^{\frac{i(i-1)}{2}} \times p_1' = n'^{\,i} \times (1-\frac{n'}{n})^{\frac{i(i-1)}{2}} \times (\frac{1}{n})$$

$(i > 1)$ ∎

Statement 2: In ad hoc network, the possibility p_i that there is another i $(i > 1)$ links path between any neighbor nodes is: $p_i = \dfrac{\dfrac{(n')^i \times (1-\frac{n'}{n})^{\frac{(i+1)(i-2)}{2}}}{n}}{n}$, $(i > 1)$

Proof: According to Statement 1, we know the possibility p_i' that there is only a i $(i > 1)$ links path between any two un-neighbor nodes. Then it can be obtained that the possibility that there is a i $(i > 1)$ links path between any two nodes is: $\dfrac{p_i'}{(1-\frac{n'}{n})}$.

And thus, the probability that there is a i $(i > 1)$ links path between any two neighbor nodes is:

$$p_i = \frac{n'}{n} \times \frac{p_i'}{(1-\frac{n'}{n})} = \frac{\dfrac{(n')^i \times (1-\frac{n'}{n})^{\frac{(i+1)(i-2)}{2}}}{n}}{n}, (i > 1)$$ ∎

4 Simulations

GloMoSim [5] is used here to realize simulations of PatchODMRP and NSMP protocols. In the simulations, 50 wireless mobile nodes, which move around over a square (1000m×1000 m), form an ad hoc network; the radio transmission power of the mobile nodes is 15dBm. During the 500s simulation period, the nodes move according to the "random waypoint" model without pause time.

Fig1 describes the relationship between local recovery probability and communication radius. From the simulation results, we can know that, when the mobile nodes have the reasonable communication radius, the local route maintenance can amend most link failures. Three-hop PatchODMRP has the strongest local route maintenance; NSMP has a weaker the local route maintenance of than that of PatchODMRP; two-hop PatchODMRP has the weakest local route maintenance.

Fig2 describes the local control overhead of these protocols. In Fig4, the control overhead of global flooding is set 1, and the control overhead of other protocols is related to that of global flooding. From the simulation results, we can know that, the local control overhead of NSMP is the highest; the local control overhead of two-hop PatchODMRP is the lowest. The scope of local route maintenance determines the control overhead of local route maintenance. Therefore, NSMP has the largest local route maintenance scope; two-hop PatchODMRP has the smallest local route maintenance scope.

Fig3 describes the data delivery ratio of these protocols as a function of sources increases. When there are few sources in group, the ability of their local route maintenances determine the stability of their forwarding mesh; the stability of their forwarding mesh determines their data delivery ratio. Therefore, when there are few sources in group, three-hop PatchODMRP has the highest data delivery ratio; two-hop PatchODMRP has the lowest data delivery ratio. When there are many sources in multicast group, their control overhead determines the wireless bandwidth acquired by data packets for their transmissions, and the wireless bandwidth for data transmissions determines the data delivery ratio. Therefore, when there are many sources in group, two-hop PatchODMRP has the highest data delivery ratio because of its lowest control overhead; NSMP has the lowest data delivery ratio because of its highest control overhead.

From the results of mathematic analysis and simulation, the performance of these local route maintenances is known. The local route maintenances of three-hop PatchODMRP and NSMP is stronger. However, their control overhead is higher. The control overhead of two-hop PatchODMRP is much lower. However, its local route maintenance is weaker, and some link failures can't be amended when the communication radius of mobile nodes is small. Therefore, PatchODMRP outperforms NSMP. However, PatchODMRP still has some shortcomings. Therefore, the local route maintenance scope of PatchODMRP should be reduce further without reducing its functions by some aiding nodes to is improve its scalability when the number of nodes increase.

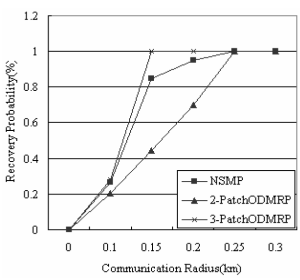

Fig. 1. Relationship between local recovery probability and communication radius

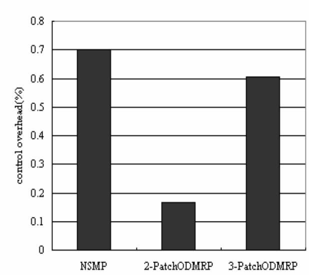

Fig. 2. Control overhead of local route maintenance

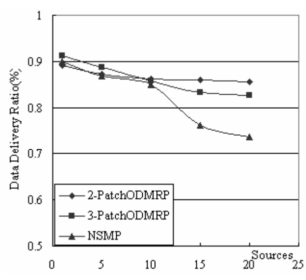

Fig. 3. Data delivery ratio as a function of sources

5 Conclusions

In this paper, we analyze the characters of local route maintenance of both NSMP and PatchODMRP by mathematic analysis and simulations. From the mathematic analysis and simulation results, we know that, the overhead of these local route maintenances is still high, and they scale poor when the number of sources increases. Therefore, we should reduce local route maintenance scope further without affecting its function.

References

[1] Mobile Ad-Hoc Network (MANET) Working Group [Online]. Available http://www.ietf.org/html.charters/ manet-charter.html.

[2] G Aggelou, R Tafazolli, "RDMAR: a bandwidth-efficient routing protocol for mobile ad hoc networks", Proceedings of The Second ACM International Workshop on Wireless Mobile Multimedia (WoWMoM), Seattle, WA, August 1999.

[3] Seungjoon Lee, Chongkwon Kim. "Neighbor supporting ad hoc multicast routing protocol". MobiHOC. 2000 First Annual Workshop on Mobile and Ad Hoc Networking and Computing, 2000.

[4] *Meejeong Lee; Ye Kyung Kim*. "PatchODMRP: an ad-hoc multicast routing protocol" Information Networking, 2001. Proceedings. 15th International Conference on, 2001

[5] Wireless Adaptive Mobility Lab. DEPT of Comp. SCI, UCLA "GloMoSim: A Scalable Simulation Environment for wireless and wired Network System: http://pcl.cs.ucla.edu/projects/domains/glomosim.html