Hierarchical Cellular-Based Management for Mobile Hosts in Ad-Hoc Wireless Networks

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Abstract

In this paper, we propose a hierarchical Cellular-Based management model for Mobile Ad Hoc Network. Under the proposed management model, mobile host can construct a stable communication path with fewer flooding messages and smaller number of hop count. In the first level management, we select a host as manager to take the responsibility of constructing communication path and managing the mobile hosts in specific cellular region such that the number of flooding packets can be largely reduced. The second level management is also proposed to reduce the number of hop count and improve the efficiency for constructing a QoS routing path. We compare the Cellular-Based management model with Triangular and Zone based management models. Performance evaluation shows that Hierarchical Cellular-Based management has a better behavior in reducing the number of flooding messages and hop count of routing paths.

1. Introduction

Different from the static network, Ad Hoc networks have no infrastructure. Each mobile host acts as a router that relays information from one neighbor to others. Packet flooding [1][4] is the general technique to establish a routing path from source mobile host to the destination. To reduce the amount of flooding packets, protocol proposed in [2] partitions the MANET into several clusters. Hosts in each partitioned cluster will vote for a header as the manager of this cluster. Host desired to establish a communication path should firstly send a request packet to its manager. Manager that receives the request packet will relay the packet to neighboring managers in a flooding manner until the manager of the destination host is found. The proposed management protocols alleviate the flooding phenomenon but induce the management overhead.

Some other location-aware protocols [3][5] use GPS to provide the location information for establishing routing path. In [3], the MANET is geographically partitioned into several grids (or called zones). Equipped with GPS, host can identify which grid it is located. In each grid, a host that is geographically near the center location of this grid will be considered as a manager for executing the route search. However, the size of grid is not determined. The movement of manager in a large grid will incur a situation that the signal strength of manager is too weak to directly communicate with neighboring managers. In this case, a gateway host is needed to relay the manager's message to neighboring managers.

To efficiently establish a communication path, alleviate the flooding phenomenon, minimize the data of routing table and increase the stability, we offer a two-level Cellular-Based management protocol in this paper. In what follows, we first present one-level management protocol. The two-level management and QoS routing protocols are then illustrated.

2. One-Level Cellular Based Management

In the Cellular-Based Management, the

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MANET is geographically partitioned into several disjoint and equal-sized cellular regions. We assume that the manager of one region can directly communicate with managers of the neighboring regions. Let the signal radius of each host be S. Here, we discuss and compare the partitioning of MANET into several basic units of Triangle, Zone, and Cellular.

2.1 The Selection of Manager

Assume that each host is equipped with GPS. A host that is nearest to the center location of a cellular will be voted as a manager by all hosts in the cellular. This will guarantee that manager will not be changed frequently due to mobility. A manager should broadcast its ID to other members, receive all member's ID, and keep these IDs in its cache table. Manager of a cellular should update the member information according to the mobility of all hosts in this cellular. Whenever the manager is going to move to another cellular, it should select a candidate host that is nearest to the center of the old cellular to be manager. Manager then transfers the contents of its table to the new candidate manager.

2.2 The Size of a Cellular

If the size of cellular is too large, manager can not directly communicate with neighboring managers. This will cause additional overhead such as maintaining gateway. This factor gives an upper bound of the size of a cellular. The size of a cellular can be computed as

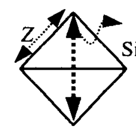
$$Size\ of\ Cellular = \frac{3\sqrt{3}}{26} S^2 \cong 0.199852 S^2$$

for a given signal strength S. According to this cellular size, MANET can be partitioned into a minimal number of cellular such that each manager can directly communicate with other neighboring managers.

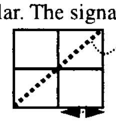
To illustrate that the Cellular-Based partition has good features in reducing flooding message, we compare the cellular-based partition with the triangular-based and the zone-based [3][5] partition in what follows. The distance of signal strength of a mobile host is assumed to be S. To satisfied the factors mentioned before, the size of a basic triangular and a basic zone is respectively

$$Tri = \frac{\sqrt{3}}{12} S^2 \cong 0.144337 S^2 \text{ and } Zone = \frac{1}{8} S^2 = 0.125 S^2$$

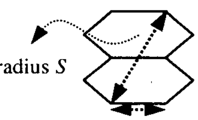
To ensure that each manager can directly communicate with neighboring managers, in the worst case, we set the maximal distance of two neighboring cells by the value of S, as shown in Figure 1.



(a) MANET is partitioned by shape of triangular. The signal radius is $\sqrt{3}$ Z.



(b) MANET is partitioned by shape of grid. The signal radius is $2\sqrt{2}$ Z.



(c) MANET is partitioned by shape of cellular. The signal radius is $\sqrt{13}$Z.

Figure 1. The MANET is partitioned by different shapes.

Since the size of each cell, partitioned by a specific shape, is known, we may evaluate the number of cells in MANET. The number of partitioned cells can be used for the measurement of the number of flooding packets since there is a manager in each cell and only the manager can relay the flooding packets. We assume the measured MANET is with size K*K. Let $Cost_T$, $Cost_Z$, and $Cost_C$ respectively denote the amount of flooding packets in the environment that the MANET is partitioned by shapes Triangular, Zone, and Cellular. The ratio of flooding cost is listed as follows.

$$Cost_T : Cost_Z = 0.144337 S^2 : 0.125 S^2 \cong 0.875$$

$$Cost_C : Cost_Z = 0.125 S^2 : 0.199852 S^2 \cong 0.624$$

The Triangular-Based partition saves almost 12.5% flooding packets than Zone-Based. Moreover, the Cellular-Based partition saves almost 37% flooding packets than Zone-Based partition. This concludes that the Cellular-Based partition is cost effective in reducing flooding packets.

In addition to the number of flooding packets, we measure the improvement in reducing the number of hop of a routing path by setting some specific angles formed by source and destination hosts. The measurement is shown in Table 1.

Table 1. Measurement of hop count of routing path by applying Cellular and Zone based partition schemes.

Shape of Cell	Angle formed by source and destination hosts				
	0	30	45	60	90
Optimal	100%	100%	100%	100%	100%
Cellular	240%	208%	328%	240%	208%
Zone	283%	283%	283%	283%	283%

In Table 1, value in the "Optimal" row denotes the minimal hop count that the routing path is established by flooding without applying any management. In this condition, hosts can establish a shortest routing path without the constraint that only the manager can establish the routing path as defined in Cellular and Zone management models. Value in "Cellular" and "Zone" rows denotes the ratio of hop count compared to the corresponding value in "optimal" case. When the angle formed by source and destination hosts is 45, as shown in Figure 2, Zone-Based management needs one hop but Cellular-Based management needs two hops to set up the routing path from source host to destination host. However, in most cases, the Cellular-Based management has a better behavior than Zone-Based management.

2.3 Cellular-Based Routing Protocol

Member host that hopes to build a communication path to another host will issue a route request packet RREQ(source-id, broadcast-id, destination id, hop-count, timeout) to its manager. As the manager received the RREQ packet, it checks first whether the destination host is appeared in its table or not. If the destination host appeared in its member table, manager will issue a reply packet RREP(source-id, destination-id, my-id, previous-id) back to the manager of the source host such that routing path can be constructed. The flooding operation is then performed in manager level until the destination host is found. Figure 3 depicts the routing path construction from source host S to destination host D.

Although applying managers can largely reduce the number of flooding during path construction, however, the routing path constructed by managers may have a larger number of hop count. In the next section, we introduce the two-level cellular-based management to additionally reduce the number of hop count for constructing a QoS routing path.

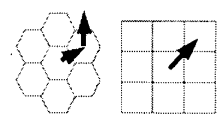


Figure 2. When the angle formed by source and destination hosts is 45, Grid-Based management has a better behavior than Cellular-Based management.

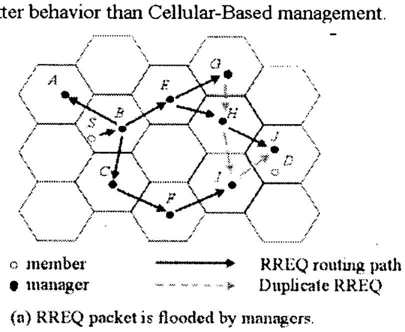
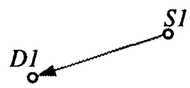


Figure 3. An example of route construction from source host S to destination host D.

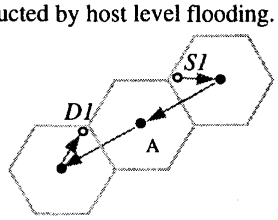
3. Two-Level Cellular-Based Management

There exist two problems in one-level management. First, it is possible that two routing paths pass through the same cellular. Under this condition, a QoS routing request is difficult to satisfied. This is because that a manager may not afford the bandwidth requests of two routing paths.

We call this bandwidth-congestion problem. Another problem of one-level management is that the number of hop count may increase, compared to the routing path constructed by host flooding. In Figure 4(a), source host *S1* can communicate with destination host *D1* in a one-hop distance. However, the path construction done by managers will establish a 4-hop communication path as shown in Figure 4(b). In this section, a two-level cellular-based management is proposed to solve these two problems.



(a) A one-hop communication path is constructed by host level flooding.



(b) A 4-hop communication path is constructed by manager-level flooding.

Figure 4. Manager-level flooding will possibly increase the number of hop count of a communication path.

3.1 Two Level Cellular-Based Partitioning

The main idea of two-level cellular-based management is to group seven small cellulars as a super cellular. One of the seven managers that is nearest the center location of super cellular will be considered as the header of the super cellular. As shown in Figure 5, cellulars that are filled with the same symbol are considered as a super cellular. For example, cellulars marked by A_0, A_1,..., A_6 are grouped into a super cellular and manager of cellular A_0 is the header of the super cellular. A header of a super cellular will record the seven managers of the grouped cellular. Only headers will participate the flooding operation in constructing a routing path. When the path is constructed by header, the header can assign one of its manager to serve as a relay node in the constructed path. This will avoid the bandwidth-congestion problem since header can assign two different managers to serve as relay nodes for two different paths which pass through the same super cellular simultaneously.

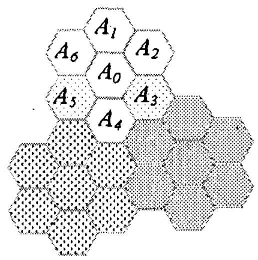


Figure 5. Two-level cellular-based partition.

To guarantee that header can directly communicate with neighboring headers, the size of small cellular should be reduced, compared to one-level cellular-based management. The size of small cellular and super cellular are respectively

$$\textit{Size of small cellular} = \frac{3\sqrt{3}}{194} S^2 \text{ and}$$

$$\textit{Size of super cellular} = \frac{21\sqrt{3}}{194} S^2.$$

3.2 Two Level Cellular-Based Management

Among super cellular, only headers can communicate with each other. Whenever a header moves from its current cellular to another cellular, a new manager of the current cellular will be selected as the candidate for header. The creation of new manager is similar to the one-level cellular-based management as mentioned in the previous section. Within a basic cellular, the management rules are similar to those mentioned in one-level cellular-based management.

3.3 QoS Routing Protocol for Two-Level Cellular-Based Management

To reduce the number of hop count, the bandwidth table stored in each header consists of 49 rows and 49 columns, as shown in Fig 6. Value in the bandwidth table denotes the bandwidth of the corresponding two managers. Note that two

	E_0	E_1	E_2	E_3	E_4	E_5	E_6	....
B_0	2	3	3	2	1	0	0	
B_1	0	3	2	0	0	0	0	
B_2	0	3	2	0	0	0	0	
B_3	1	2	3	1	2	0	0	
B_4	2	3	1	3	2	0	0	
B_5	0	0	0	0	0	2	3	
B_6	0	0	0	0	0	2	S	
⋮								

Figure 6. The bandwidth table stored in header C_0.

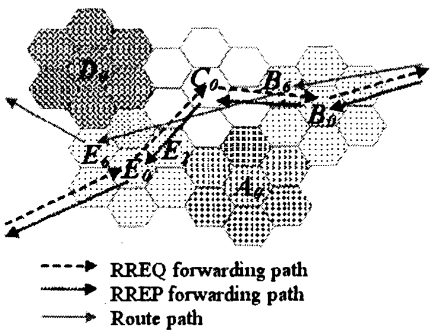


Figure 7. One hop count is reduced by header C_0.

managers whose distance is larger than the signal distance S will have a zero value in the bandwidth table. During the path constructing, the RREQ packet is relayed by header in a flooding manner. Whenever the header of destination host receives the RREQ packet, it selects a path with minimal hop count and issues the RREP packet backward to the header of source host. When the header receives the RREP packet, it looks up the bandwidth table and determines that whether the route path can jump itself and directly relay message from one manager of neighboring super cellular to another manager of other neighboring super cellular. Figure 6 shows the bandwidth table stored in header C_0. As shown in Fig 7, header C_0 receives the RREP packet issued by header B_0, it checks whether the downstream manager B_i can directly communicate with upstream manager E_j for some $0 \leq i, j \leq 6$. In Figure 7, since manager B_6 can directly communicate with manager E_6 and the bandwidth meets the QoS minimal requirement, header C_0 determines to jump itself and one hop can be saved in the constructed routing path. As a result, the number of hop of constructed routing path can be reduced by headers when they receive the RREP packet.

4. Performance Study

The environment of our simulation is stated as follows. The size of MANET is 100* 100 basic units. Signal strength is set to 10 basic units. Figures 8 displays the comparison of one-level zone-based and cellular-based management in the number of flooding packets. The location of mobile host is randomly generated in MANET. To guarantee that two neighboring managers can directly communicate each other, the maximal size of a basic zone is smaller than one of a basic cellular. When the number of hosts is few, a lot of zones have no host. This is due to that the number of basic zone is more than the number of basic cellular. It causes that the zone-based partition can not find any routing path, in most cases, for a pair of randomly generated source and destination hosts. The flooding packet will not be spread on those zones that have no host. This is the reason why the zone-based management has a smaller number of flooding packets than cellular-based management. The phenomenon can be found in Figure 8 for the number of host less than 600. The low successful rate can be checked in Figure 9. Consider Figure 9. As the number of hosts is more than 600, almost all zones and cellulars have host. The zone-based management has more flooding packets than cellular-based management, as shown in Figure 8.

Figure 10 shows the comparison of hop count of zone-based and cellular-based partitioning schemes. Figure 11 displays the effect of two-level cellular management. Compared with the one-level cellular management, the two-level cellular management has fewer hop count.

5. Conclusions and Future works

In this paper, we proposed the two-level cellular-based management for Mobile Ad-Hoc network. In comparison with the Zone (or

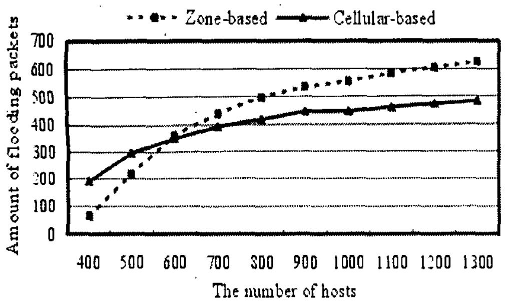


Figure 8. The comparison the amount of flooding packet in one level management. The signal Strength is set to 10 units.

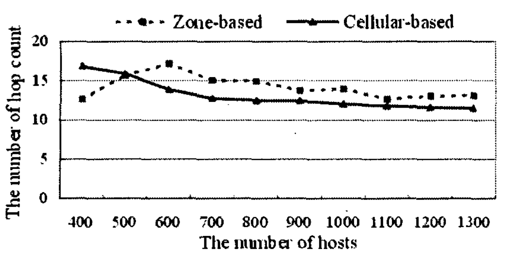


Figure 10. The comparison of one level zone-based management and cellular-based management in the number of hop count.

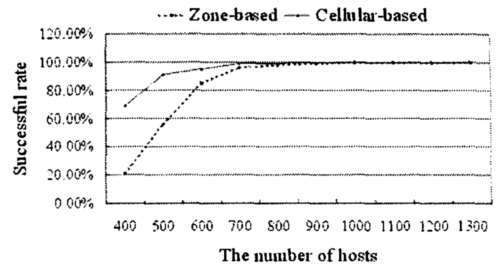


Figure 9. The comparison of one level zone-based management and cellular-based management in the successful rate for finding a routing path.

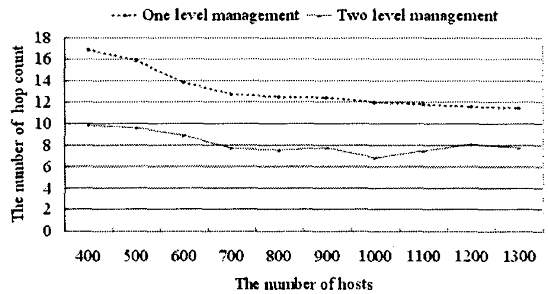


Figure 11. The comparison of two level zone-based management and cellular-based management in the number of hop count.

Grid)-Based management model, the one-level cellular-based management generates fewer flooding packets during path constructing. To resolve the bandwidth congestion and reduce the number of hop of the established routing path, we proposed two-level cellular-based management. The simulation results show that Cellular-Based management has a better behavior in reducing the number of flooding packet and the number of hop of a routing path. The future work is to develop multicasting, geocasting, broadcasting protocols based on the Cellular-Based management model.

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