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# Fuzzy Logic based Mobility Management Scheme in MANETs

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***Abstract***

*Mobility management is an important issue in Mobile Ad Hoc Networks (MANETs) because location information of mobile nodes is frequently changed and it aggravates the performance in MANETs drastically. In this paper, we propose a fuzzy logic based mobility management scheme using group quorum system by considering the mobile nodes' locality in order to manage location information of mobile nodes in MANETs efficiently. The proposed scheme selects mobility databases adaptively from group quorum system by considering the degree of locality of a mobile node. The performance of the proposed scheme is evaluated by an analytical model and compared with that of existing mobility management scheme.*

***Keywords:*** *Mobility Management, Quorum System, Fuzzy Logic, MANETs*

## 1. Introduction

Recently, one research issue that has attracted a lot of attention is the design of MANETs consisting of a set of mobile hosts that may communicate with one another and roam around at their will. MANETs are an emerging essential technology that allows the instant establishment of communication network for private or military applications. MANETs enable wireless communication among mobile hosts without relying on a fixed infrastructure. In these networks the mobile hosts themselves forward data from a sender to a receiver, acting as both router and end-system at the same time. In MANET architecture, there is no pre-existing fixed network infrastructure and it is a self-organizing network. Nodes in MANETs are mobile hosts with similar transmission power and computation capabilities. Direct communication between any two nodes is allowed when adequate radio propagation conditions and network channel assignment exist. Otherwise, the nodes are communicating through multi-hop routing. Mobility of network nodes, limited resources like bandwidth and battery power, and potentially large number of nodes make routing and mobility management in MANETs extremely challenging problems. Due to the limited bandwidth, various network connectivity and frequent topology changes caused by node's mobility, existing routing algorithms for wired networks would not be operated well in MANETs. Recently, many researches for mobility management are carried out actively by using location information of mobile nodes. The mobility management is an important issue in MANETs because location information of mobile nodes is frequently changed and it aggravates the performance in MANETs significantly.

The main contribution of this paper is to propose a fuzzy logic based mobility management scheme in

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MANETs. In a proposed mobility management scheme, the topology of wireless mobile Ad-Hoc networks is divided by several logical regions of two-layered grid structure, and single home region is selected from each two dimensional region by using the mapping function. These selected N home regions are composed of logically spread surface quorum system, and the quorum system is constructed from this system by considering the fuzzy logic for the mobility of mobile nodes. If one mobile node updates its location, quorum is selected from the quorum system by considering the fuzzy logic of that mobile node, and then stores the location information of the mobile node to all nodes in a selected quorum.

The rest of the paper is organized as follows. Section 2 gives a brief description of related works for mobility management in MANET. Section 3 illustrates the proposed fuzzy logic based mobility management scheme using group quorum system in MANET. Section 4 evaluates the performance of the proposed mobility management scheme by an analytical model. Finally, Section 5 concludes the paper.

## 2. Related Works

A location service scheme consists of two major procedures such as the location update and the location search algorithm. Recently, lots of researches for the location based service in wireless mobile ad-hoc networks were announced. We summarize the related works for this topic in this section.

Hierarchical Location Service (HLS) [1, 2] divides the area covered by the network into a hierarchy of regions. The lowest level regions are called cells. Regions of one level are aggregated to form a region on the next higher level of the hierarchy. Distance Routing Effect Algorithm for Mobility (DREAM) [3] uses flooding to spread position information in a location service. With DREAM, each node floods its position information on the network with varying flooding range and frequency. Home-zone [4] does not require flooding in a location service. In this location service, each node is assigned a home-zone area in wireless mobile ad-hoc networks via a hash function.

Grid Location Service (GLS) [5] divides the area containing the mobile ad-hoc network into a hierarchy of square forming a quad-tree. Each node selects one node in each element of the quad-tree as a location server. Distributed Location Management Scheme (DLM) [6] partitions the mobile node deployment region into a hierarchical grid with square of increasing size. The location service is offered by location servers assigned across the grid, storing node location information.

Li et. al. [7] studied many different query methods for randomized database group scheme and compared with their performances. Especially, the optimal size of the both update group and query group are determined in this paper. Camp [8] has developed and evaluated the performance of three location services: the Simple Location Service (SLS), the DREAM Location Service (DLS) and the Reactive Location Service (RLS).

## 3. Fuzzy Logic based Mobility Management Scheme

### 3.1 System Model

Given a square region of area, mobility management scheme divides the topology of a wireless mobile Ad-Hoc network by G logical unit regions, which are referred to as Region 1 (Order-1 regions). Assume that each node is aware of the size of topography as well as the size of a Region 1. Then, it combines several Order-1 regions to form Region 2(Order-2 region). Each node selects single home region in each Order-2 region through a mapping function that maps roughly almost the same number of nodes in Order-1 regions to each Order-2 region [9]. At any given time, a relatively limited number of key locales in the network, where important events or activities are taking place, are referred to as focus or hot locales. The mobile nodes reside in this locales are called as focus or hot nodes. Otherwise, it is referred to as cold locales and cold nodes respectively [10]. The mobile Ad-Hoc networks can be modeled as a set of N mobile nodes roaming around freely in the predetermined 3-dimensional region. Furthermore, mobile node selected in each home region plays a role of a location server maintaining the location information of other nodes in a system. Figure 1 shows the system model adopted in this paper. As shown in the figure, cells are grouped hierarchically into regions of different levels. A number of cells form a Region 1. A number of Region 1s

form a Region 2 and so on.

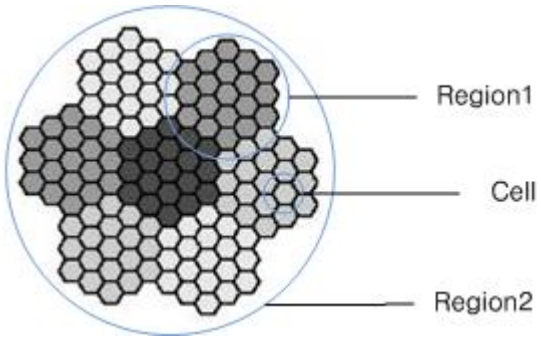


**Figure 1. System Model**

### 3.2 Group Quorum System

Location update or query operation for location information of a mobile node is performed by a fuzzy logic based group quorum system in a proposed mobility management scheme [9]. Group quorum system can be constructed from the unfolded surface quorum system with home regions in a wireless mobile Ad-Hoc network. If we spread three sides of a cubic on the plane, the group quorum system, $S_4 = (C_1, C_2, C_3, C_4)$ can be constructed. Each quorum in $C_1$ corresponds to the vertical line crossing the right-most column of the square. Each quorum in $C_2$ corresponds to the horizontal line and vertical line of the next two squares of the center column respectively. Moreover, each quorum in $C_3$ corresponds to the horizontal line and vertical line of the next square of the left-most column respectively. Finally, each quorum in $C_4$ corresponds to the horizontal line crossing lower three squares.

In general, each $C_i$ in $S_m$ requires m-1 squares. By sharing more than one square of another m-1 cartel with each other, lines corresponding to these two cartels intersect exactly one or more than one nodes on this square. On the whole, there are $\frac{m(m-1)}{2}$ squares. Let k be the width of each square. Then, since each square is composed of $k^2$ nodes, the total number of nodes in $\frac{m(m-1)}{2}$ squares are $k^2\frac{m(m-1)}{2} = h$, where, h represents the total number of home regions composing the system. Therefore, $k = \sqrt{\frac{2h}{m(m-1)}}$ , m>1. The size of quorum is $q = k(m-1) = \sqrt{\frac{2h(m-1)}{m}}$.

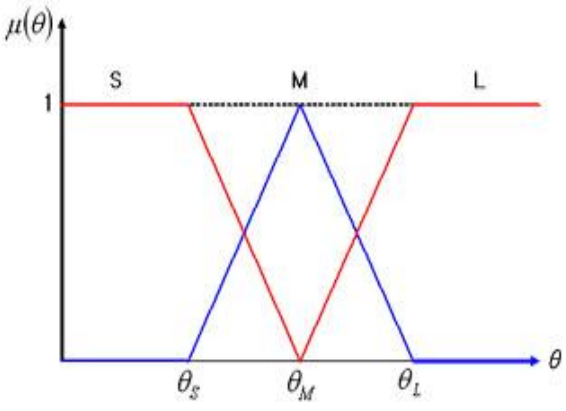


**Figure 2. The Basic Fuzzy Set for POM**

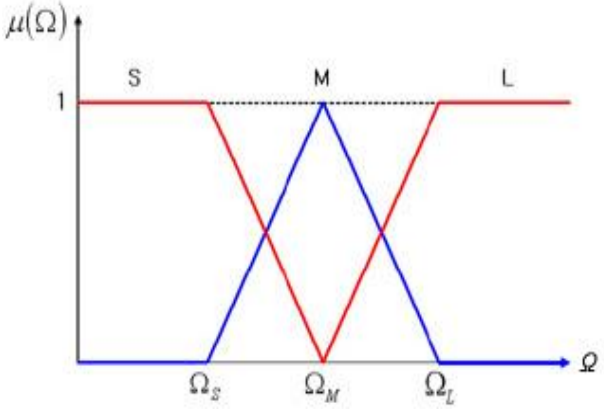


**Figure 3. The Basic Fuzzy Set for PIC**

The major factors those affect the gravity of locality of mobile nodes in wireless mobile Ad-Hoc network during a given time are determined by the number of location updates and the number of incoming calls in that region. In this paper, the gravity of locality of the mobile node is determined by applying the fuzzy logic for the number of location updates and the number of incoming calls in that region during some period of time. Figure 2 shows the basic fuzzy sets for the probability of moves (POM) of mobile nodes, which is proportional to the number of location updates in the region where the mobile node resides.

Figure 3 shows the basic fuzzy sets for the probability of incoming calls for the mobile node (PIC), which is proportional to number of incoming calls in the region where the mobile node resides. They are mapped by three fuzzy sets: S (small), M (medium), and L (large) by a mapping function respectively. Figure 4 shows the fuzzy control rules for the number of location updates and the number of incoming calls in the region where the mobile node resides

| POM \ PIC | Small | Medium | Large |
|---|---|---|---|
| Small | $QS_m$ | $QS_h$ | $QS_h$ |
| Medium | $QS_c$ | $QS_m$ | $QS_h$ |
| Large | $QS_c$ | $QS_c$ | $QS_m$ |

(Input Variable)
POM : Probability of Moves
PIC : Probability of Incoming Calls
(Output Variables)
$QS_c$ : cold, $QS_m$ : medium, $QS_h$ : hot

**Figure 4. The Fuzzy Control Rules**

## 4. Performance Evaluation and Analysis

The performance of the proposed fuzzy logic based mobility management scheme is to be evaluated by an analytical model. The mobility management cost is estimated in terms of a total location management cost that is the sum of a location update cost and a location query cost as shown in the equations (1) below:

$$C_{total} = \{p_{H_1} C_{u-hot} + P_{M_1} C_{u-med} + P_{c_1} C_{u-cold}\} + \frac{\lambda}{\mu}\{P_{H_2} C_{q-hot} + P_{M_2} C_{q-med} + P_{c_2} C_{q-cold}\} \quad (1)$$

where, $\frac{\lambda}{\mu}$ represents the call-to-mobility ratio. In this equation, $C_{u-hot}, C_{u-med}$ and $C_{u-cold}$ are the location update costs in case of the mobile node updating its location is hot, medium, or cold respectively. Furthermore, $C_{q-hot}, C_{q-med}$ and $C_{q-cold}$ are the location query costs in case of the target mobile node is hot, medium, or cold respectively.

Finally, $P_{H_1}, P_{M_1}, P_{C_1}$ are the probabilities that the mobile nodes updating their locations are hot, medium, or cold node respectively, and $P_{H_2}, P_{M_2}, P_{C_2}$ are the probabilities that the target mobile nodes are hot, medium, or cold node respectively.

Table 1 shows the main parameters of the analytical model for the performance evaluation of the proposed mobility management scheme.

**Table 1. Main parameters of Analytic Model**

| Parameter | Value | |
|---|---|---|
| G | 48 by 48 | |
| K | 4 | |
| h | 147 | |
| m | 4 | |
| q | 21 | |
| $P_{H_1}, P_{M_1}, P_{C_1}$ | Case 1 | (0.25, 0.5, 0.25) |
| | Case 2 | (0.2, 0.6, 0.2) |
| $P_{H_2}, P_{M_2}, P_{C_2}$ | Case 1 | (0.5, 0.25, 0.25) |
| | Case 2 | (0.6, 0.2, 0.2) |

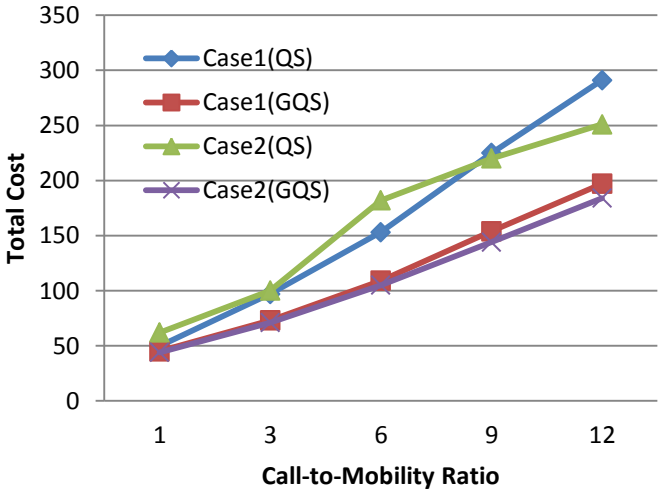


**Figure 5. Results of the Performance Evaluation**

Figure 5 shows the results of performance evaluation in terms of the total location management cost over the call-to-mobility ratio for both the mobility management scheme using fuzzy logic based group quorum system (GQS) proposed in this paper, and the mobility management scheme based on the existing Uniform Quorum System (QS). As shown in the figure, the total location management cost of the proposed scheme (GQS) is much lower than those of the existing uniform quorum system based mobility management scheme (QS) regardless of the call-to-mobility ratio in both cases. Since the quorum size of our GQS is much smaller than that of the QS by applying the fuzzy logic to the group quorum system, and the location information of the mobile node is stored in home regions adaptively by considering the gravity of locality with the fuzzy logic, we know that the performance of our mobility management scheme is much superior than that of the QS scheme in higher call-to-mobility ratio because of its locality in a location query operation. Furthermore, both the number of control messages and electric power used in the mobility management are also reduced by using fuzzy logic based location update considering the gravity of locality in location update operation and by fulfilling the location query using small-sized quorum in location query operation. Moreover, the load balancing for the location query on the home regions in a system can be achieved because the number of quorums included in arbitrary i-th home region are the same.

## 5. Conclusion

Mobility management is an important issue in Mobile Ad Hoc Networks because location information of mobile nodes is frequently changed and it aggravates the performance in MANETs drastically. In this paper, we propose a mobility management scheme using fuzzy logic based group quorum system, and evaluate the performance of the proposed scheme by an analytical model in terms of the total location management cost over call-to-mobility ratio. According to the results of the performance evaluation, we know that the performance of the proposed mobility management scheme is much superior than that of the existing uniform quorum system based mobility management scheme. It is because not only the home regions storing the location information of a mobile node in location update operation of our mobility management scheme is much smaller than those of the existing mobility management scheme by considering the gravity of locality with the fuzzy logic, but also the search space in case of the call delivery are also reduced by fulfilling the location query using small-sized quorum in location query operation.

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