이동 무선망에서 무단절 통신을 위한 퍼지 멀티캐스트 방법의 설계 및 평가

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요 약

무단절 통신의 목표는 이동 사용자에게 단절 자유 서비스를 제공하는데 있으며, 이동 서비스의 단절은 활동적 핸드오프에 의해 발생된다. 이동 무선망에서 무단절 서비스에 대한 완전 보장을 요구하지 않으나 매우 빈번한 단절을 허용하지 않는 많은 사용자 응용들이 있다. 이 논문에서는 무단절 서비스에 대한 언어적 보장을 제공하는 퍼지 멀티캐스트 방법을 제안한다. 무단절 서비스에 대한 언어적 보장이 이동 사용자에 의해 명세되면, 제안하는 퍼지 멀티캐스트 방법은 이동 호스트의 이동 방향과 이동 속도를 예측하고, 퍼지 논리에 의해 그 이동 호스트를 위한 데이터 패킷은 모든 이웃 셀이 아닌 일부 이웃 셀에게 전송된다. 시뮬레이션 결과, 우리는 다음 사항들을 알 수 있었다. 첫째, 퍼지 멀티캐스트 방법은 정적 대역폭 사용을 상당히 감소시키고 또한 무단절 서비스에 대한 언어적 보장을 제공한다. 둘째, 무단절 서비스 확률은 이동 사용자의 언어적 QoS와 이동 호스트의 이동 방향에 의해 결정되고, 특히, 이동 사용자의 언어적 QoS에 의해 많은 영향을 받는다. 그러므로 퍼지 멀티캐스트는 이동 사용자의 언어적 QoS 명세로 무단절 서비스에 대한 좋은 차등 서비스를 제공한다.

Design and Evaluation of a Fuzzy Multicast Method for Seamless Communication in Mobile Wireless Networks

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ABSTRACT

The goal of seamless communication is to provide disruption free service to a mobile user. A disruption in mobile service could occur due to active handoffs. There are many user applications that do not require total guarantee for disruption free service, and also not tolerate very frequent disruptions. This paper proposes a fuzzy multicast method that provides a linguistic guarantee for disruption free service. The linguistic guarantee for disruption free service is specified by a mobile user, then the proposed method forecasts the direction and velocity of a mobile host, and data packets for the mobile host are transmitted to a part of neighbor cells instead of all neighbor cells by the fuzzy logic. Based on the results of simulations, we know that the following details. Firstly, the fuzzy multicast method significantly reduces the static network bandwidth usage and also provides linguistic guarantee for disruption free service. Secondly, the probability of disruption free service is determined both by the linguistic QoS of mobile users and the direction of mobile hosts. Specially, the probability of disruption free service is affected primarily by the linguistic QoS of mobile users. Accordingly, we conclude that the fuzzy multicast provides excellent differential service for disruption free service with specifying linguistic QoS of mobile users.

키워드 : 이동 무선망(Mobile wireless networks), 무단절 통신(seamless communication), 단절 자유 서비스(disruptipn free service), QoS, 퍼지 논리(fuzzy logic)

1. Introduction

Mobile computing refers to an emerging new computing environment incorporating with both wireless and wired high-speed networking technologies. In the near future, it is expected that millions of users will have access to a wide variety of services that will be available over high-speed networks.

When a *mobile host* (MH) is engaged in a call or data transfer, it will frequently move out of the coverage area of the *mobile support stations* (MSSs) it is communicating with, and unless the call is passed on to another cell, it will be lost. Thus, the task of forwarding data between the static network and the mobile user should be transferred to a new cell's MSS. This process, known as handoff, is transparent to the mobile user. Handoff helps to maintain an end-to-end connectivity in a dynamically reconfigured network topology.

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To illustrate some of the unique features of the mobile computing environment, we consider a situation where several mobile users have opened high-bandwidth data connections. When these data connections are set up, the network ensures that the users receive some guaranteed quality of service (such as delay and jitter bounds, minimum and maximum bandwidth requirements and maximum loss bound, etc.). Since these users are all mobile, it is possible that many of them could move into the same cell. In such a situation, it is more likely that the available bandwidth of the cell could be exceeded and the original quality of service parameters will be violated. This situation does not arise in high-speed networks because users are not mobile during the lifetime of the connection [2].

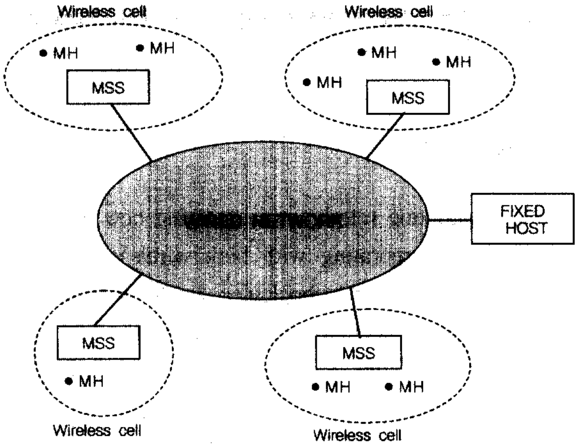
Mobility of users is attended with several network management problems. These problems are generally classified into mobility and connection management. This paper deals with the seamless communication problem that provides disruption free service to mobile users, which is related to the connection management in mobile wireless networks. Providing disruption free service is much stronger requirement than simple connection-oriented services. In addition to maintaining the connection, it need to guarantee that the delay experienced by the data packets over the network is less than some fixed time called deadlines. The deadline is determined by the *quality of service* (QoS) according to the requirements of the users. The goal of seamless communication is to provide disruption free service to a mobile user. Disruption in mobile service could occur due to active handoffs since traditional protocols require the old MSS to forward data packets to the new MSS. Thus, every time a mobile user moves into a new cell during the connection (active handoff), the user could see some break in service while data get forwarded to it from the old MSS via the new MSS. The number of disruptions seen by the user depends on the number of handoffs incurred during the lifetime of the connection. The number of handoffs depends on the mobility pattern of the user [1, 2].

This paper proposes a fuzzy seamless communication method that provides linguistic guarantee for disruption free service. The method forecasts the cell latency of a mobile host and the neighboring cells in which the mobile host will be handoff potentially by using the MH's velocity and direction. Then the data packets for the mobile host are transmitted to only a part of neighboring cells based on the fuzzy logic after a staggered time. The method significantly reduces the static network bandwidth usage and also provides a linguistic guarantee for disruption free service.

The remainder of this paper is organized as follows. Section 2 briefly describes the model of the mobile computing system that is assumed in the rest of the paper. Section 3 describes related works for seamless communication in mobile wireless networks. Section 4 proposes a fuzzy seamless communication method considering mobility prediction that provides a linguistic guarantee for disruption free service. Section 5 evaluates the performance of the proposed method through a simulation study. Finally, concluding remarks are presented in section 6.

2. System Model

The logical view of the mobile computing system considered in this paper is shown in (Figure 1). A host that can move while retaining its network connections is a *mobile host* (MH). The infrastructure machines that communicate directly with the mobile hosts are called *mobile support stations* (MSS). A *cell* is a logical or geographical coverage area under a MSS. All MHs that have identified themselves with a particular MSS are considered to be local to the MSS. A MH can directly communicate with a MSS only if the MH is physically located within the cell serviced by the MSS. At any given instant of time, a MH may belong to only one cell; its current cell defines the location of a MH. Each MSS of cells maintains the location information for local MHs (see (Figure 2)). The location information, such as the MH's velocity and the MH's direction, is obtained through *deregister* and *register* messages those are exchanged between old MSS and new MSS when the MH is handoff.



(Figure 1) Logical view of a mobile computing system

Mh_id	mss_id	reg_time	velocity	Angle

- mh_id : MH identifier
- mss_id : MSS ientifier
- reg_time : the system time that the mobile host is rehistered at the MSS
- velocity : the average velocity of the mobile host

(Figure 2) The location information for MH in MSS

3. Previous Work

Previous works for seamless communication that guarantees disruption free service are as follows. Ghai et al. [1] proposed a multicast based solution for disruption free service. In this approach, since data packets for a MH are transmitted to the MSSs of the neighboring cells, there are data packets already waiting for it when the MH moves to a new cell, and thus there is no break in service. It is evident, however, that this approach is not effective for cost. As the number of users in the network increases, the amount of network bandwidth used up by the multicast connections is going to be high exponentially.

Singh [2] identified two additional QoS parameters those are essential to specify grades of service for mobile users. These parameters are loss profiles and probability of seamless communication; where, loss profile specifies a preferred way of discarding data packets when the bandwidth required within a cell exceeds the available bandwidth. Depending on the type of application, a mobile user may demand various probability of seamless communication. Based on the user demand, the composition of a group and the time that cells in a group begin predictive buffering are determined. In this approach, the data packets for a mobile host are transmitted to all the MSSs of neighboring cells, so that network bandwidth is wasted since all the MSSs of neighboring cells buffer data packets from the time that begins predictive buffering.

Bakshi et al. [3] proposed a staggered multicast approach that avoids unnecessary multicast to all the MSSs of neighboring cells during the connection period by using cell latency. The cell latency solely depends on the mobility model of the mobile host. Two mobility models: *pessimistic* and *optimistic* were proposed to compute the cell latency. The performance of the staggered multicast was evaluated with the overhead of network bandwidth. In this approach, even though the transmission time for data packets to all the MSSs of neighboring cells is delayed, but the transmission manner for data packets to the MSSs of neighboring cells is the same [1, 2].

Aljadhai et al. [8] proposed a framework to support predictive timed-QoS guarantees in wireless environments. The main components of the framework include a service model for QoS guarantees, a path predictability model, and a call admission control scheme. The framework determines the *most likely cluster* (MLC) of the MH, then estimates both the earliest and the latest arrival time and latest departure time for the MLC. The call admission control determines the feasibility of admitting a call using these estimates by verifying that enough resources are available in each MLC cell.

In [9, 12], a probabilistic multicast method for seamless communication is proposed, where the mobility direction of a mobile host is computed by exponential averaging, the handoff probability to each cell is computed by the numerical integration of probability density function. Because data packets are transmitted to a part of neighboring cells, this method provides better performance than other methods.

We propose a fuzzy multicast that provides a linguistic guarantee for disruption free service. Based on the location information for a MH in the MSS, the fuzzy multicast estimates the MH's velocity and direction, and forecasts both the cell latency of the MH and the neighboring cells where the MH will be handoff potentially. So, the data packets for the MH are transmitted to only the MSSs of the forecasted neighboring cells by the fuzzy logic after a staggered time.

4. Fuzzy Seamless Communication Method

In this section, we propose the fuzzy multicast that transmits data packets to only the neighboring cells where a mobile host will be handoff potentially, after a staggered time. To design the fuzzy multicast, the system has the mobility information of a MH such as mobile direction and velocity. Then, the system determines a multicast group and a multicast time using fuzzy logic and defuzzifier on the basis of the mobility information.

4.1 Mobile Direction

The mobile direction of a MH is estimated by the history of recent handoffs. The history represents the handoff from any cell among six neighboring cells to the current cell (see (Figure 3)). The forecasted mobile angle of the MH is computed by *adaptive-response-rate single exponential smoothing method* (ARRSES) [10]. The basic equation for forecasting with the method of ARRSES is as follows:

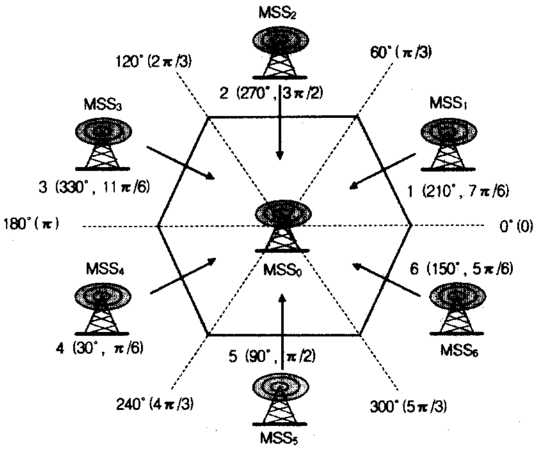
$$F_{t+1} = \alpha_t Y_t + (1-\alpha_t) F_t \qquad (1)$$

$$\text{where } \alpha_t = \left| \frac{A_t}{M_t} \right|$$

$$A_t = \beta E_t + (1-\beta)A_{t-1}$$
$$M_t = \beta\,|\,E_t\,|\, + (1-\beta)M_{t-1}$$
$$E_t = Y_t - F_t$$

In equation (1), Y_t represents the average angle that the MH enters from the last cell to the existing cell, F_t represents the forecasted mobility angle of the mobile host at the last MSS, and β is a parameter that has the value between 0 and 1. These are initialized as follows:

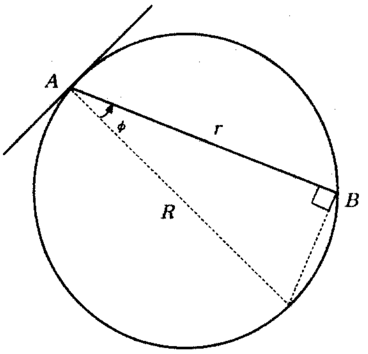
$$F_2 = Y_1$$
$$A_2 = A_3 = A_4 = \beta = 0.2$$
$$A_1 = M_1 = 0$$



(Figure 3) The average angle that the MH enters according to mobile direction

4.2 Mobile Velocity

When a mobile host crosses over cell boundary, the mobile direction of the mobile host is represented as the angle ϕ, that is, angle between the direction of the mobile host and the direction from the mobile host to the center of a cell as shown in (Figure 4).



(Figure 4) The distance from point A on cell boundary to point B on cell boundary

If we assume that the mobile host moves to any directions with equal probability, the random variable has ϕ the *probability density function* (pdf) as follows:

$$f_\phi(\phi) = \begin{cases} \frac{1}{\pi}, & -\frac{\pi}{2} \le \phi \le \frac{\pi}{2} \\ 0, & elsewhere \end{cases}$$

The distance r is computed as follows:

$$r = R\cos\phi$$

Where, R represents the hexagonal cell radius. If we assume that all the radiuses of cells are the same, the average crossing distance d is computed as follows:

$$d = \frac{1}{\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R\cos\, d\phi = \frac{2R}{\pi}$$

Let t_{c-1} be the system time of the last registration for the mobile host, and t_c be the system time of the current registration for the mobile host. The velocity of the mobile host is estimated as in equation (2).

$$v = \frac{d}{(t_c - t_{c-1})} \tag{2}$$

The cell latency is the period of time that the mobile host is going to remain in the same cell. The average cell latency T_h is computed as in equation (3).

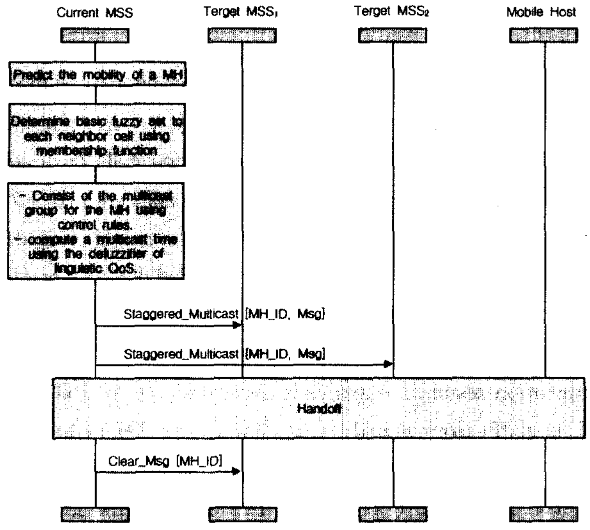
$$T_h = \frac{d}{v} = \frac{2R/\pi}{v} = \frac{2}{\pi}\cdot\frac{R}{v} \tag{3}$$

Accordingly, the mobile host resides in the cell during the average time units T_h.

4.3 Fuzzy Multicast

The sequence of actions undertaken by a fuzzy multicast method is depicted in MSC (Message Sequence Chart) of (Figure 5). The information of the cell latency and the membership degree that a MH will be handoff in each neighboring cell from the current cell are necessary to design the fuzzy multicast. First, the current MSS predicts the mobility of a MH such as mobility direction and cell latency, then determines basic fuzzy set for each neighboring cell using membership function. Second, the current MSS composes the multicast group for the MH using control rules, then computes a multicast time using the defuzzifier of linguistic guarantee for disruption free service. Third, data packets for the MH are transmitted from the current cell to the target MSSs in multicast group after a staggered time. At some time after the multicast of the MH, the MH executes a handoff operation. Fourth, the

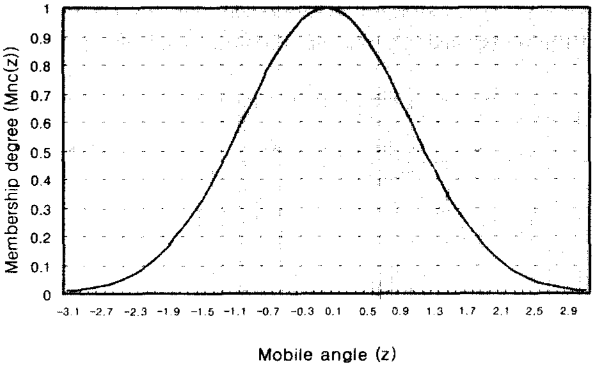
MSS in which the MH has actually been handed over notifies the previous MSS during handoff. To clear the data packets for the MH from target MSSs where the MH doesn't actually handed over, the Clear_Msg[MH_ID] is transmitted from the previous MSS to the target MSSs.



(Figure 5) Message sequence chart for fuzzy multicast

4.3.1 Membership Function

The membership function that represents the degree of handoff from the current cell to each neighboring cell is determined as follows; A variable x for adjacent angle of each neighboring cell is transformed to the standardized variable z by $z=\frac{x-F_{t+1}}{\sigma}$. Where, F_{t+1} is the forecasted mobile angle computed as in equation (1), and σ is the standard deviation for mobile angle. Let NC be the fuzzy set named "neighboring cells" where a MH can be handoff. The membership function to characterize NC is shown in (Figure 6).



(Figure 6) Membership function for NC

The fuzzy set can be defined by the membership function as in equation (4).

$$\mu_{NC}(z) = e^{-\frac{z^2}{2}} \tag{4}$$

The normalization of the fuzzy set for neighboring cells is shown in <Table 1>.

<Table 1> The normalization of fuzzy set for neighboring cells

Membership Function	Normalized full set	Normalized Regions	Basic fuzzy set
$\mu_{NC}(z)$	[0.00~1.00]	[0.00~0.15]	VL
		[0.16~0.40]	L
		[0.41~0.55]	M
		[0.56~0.75]	H
		[0.76~1.00]	VH

4.3.2 Control Rules

The fuzzy logic is used for construction of multicast group to which data packets for a MH are transmitted. The multicast group consists of neighboring cells according to the degree of disruption free service specified by the user and handoff for neighboring cell. The user of a MH can specify one out of five guarantees for disruption free service such as VS, S, M, W, VW, and the basic fuzzy set to which each neighboring cell belongs to is determined from <Table 1>. Rules for multicast group construction is shown in <Table 2>.

<Table 2> Rules for the construction of multicast group

NC / DFS	VH	H	M	L	VL
VS	MMG	MMG	MMG	MMG	MMG
S	MMG	MMG	MMG	MMG	NMMG
M	MMG	MMG	MMG	NMMG	NMMG
W	MMG	MMG	NMMG	NMMG	NMMG
VW	MMG	NMMG	NMMG	NMMG	NMMG

(input variables) NC : neighboring cell
DFS : guarantee degree of disruption free service (linguistic)
VS-Very Strong, S-Strong, M-Medium, W-Weak, VW-Very Weak

(output variable) MMG : a member of multicast group
NMMG : a non-member of multicast group

4.3.3 Defuzzifier

A system has the cell latency T_h for a MH, and the multicast doesn't need to be done during that period of time. The fuzzy multicast is to stagger the multicast initiation by the amount of time one is sure that the MH remains within a cell, i.e., for a time interval equals to the cell latency.

Let P_{d_i} be the probability of disruption during the i-th handoff, t_s be the staggered time that can be safely introduced before initiating a multicast, t_i be the cell latency before the i-th handoff, and t_{m_i} be the time spent in multicast mode before the i-th handoff. Also, let NC_{m_i} be the set of the neighboring cells where data packets are transmitted before the i-th handoff.

A disruption occurs when a mobile host initiates a handoff before multicast has not been initiated or the cell c_i where a MH moved by the i-th handoff doesn't exist in NC_{m_i}. Then, the probability of disruption during the i-th handoff can be given as:

$$P_{d_i} = \Pr[t_s > t_i \text{ or } c_i \notin NC_{m_i}]$$

If the number of handoffs occurring over the length of the connection time T_c is N_h, the average probability of disruption during a handoff, P_d is determined as:

$$P_d = \frac{1}{N_h} \sum_{i=1}^{N_h} P_{d_i}$$

In the fuzzy multicast, when a call is established between a MH and a MSS, a linguistic guarantee for disruption free service is setting by a mobile user. To compute the multicast and the staggered times, defuzzifier maps from a linguistic guarantee for disruption free service to a probability of disruption free service P_{df} (as in equation (5)), where $P_{df} = 1 - P_d$. Then, total guarantee is $P_{df} = 1.0$, and other guarantees are $P_{df} < 1.0$. Accordingly, the multicast and the staggered times for the MH are computed as in equations (6) and (7), respectively.

$$defuzzifier\left(\begin{Bmatrix} VS \\ S \\ M \\ W \\ VW \end{Bmatrix}\right) = \begin{Bmatrix} 1.00 \\ 0.75 \\ 0.55 \\ 0.40 \\ 0.15 \end{Bmatrix}$$

$$P_{df} = defuzzifier\ (a\ linguistic\ guarantee\ for\ disruption\ free\ service) \tag{5}$$

$$t_{m_i} = p_{df} \times T_{h_i} \tag{6}$$

$$t_{s_i} = T_{h_i} - t_{m_i} \tag{7}$$

5. Performance Evaluation

In this paper, we evaluate the performance of the fuzzy multicast through a simulation. The simulation parameters are shown in <Table 3>. Generally, mobile users have not only mobility patterns but also movement directions. Accordingly, we assume that the MH moves at an average angle of 180 degrees with an average standard deviation between 45 and 90 degrees. Also, the velocity of the MH is considered from a low-speed vehicle (24 Km/hr) to a high-speed vehicle (84 Km/hr), and the cell radius covers various sizes of micro cells.

〈Table 3〉 Simulation parameters

Parameter	Data value
Mobile direction (F)	$N(\pi, (sd)^2)$
Mobile velocity (v)	400±100, 650±162, 900±225, 1150±287, 1400±350 m/min (random)
Standard deviation for mobile direction (sd)	$\pi/2$, $2\pi/5$, $\pi/3$, $2\pi/7$, $\pi/4$
Cell radius (R)	100, 200, 300, 400, 500 m

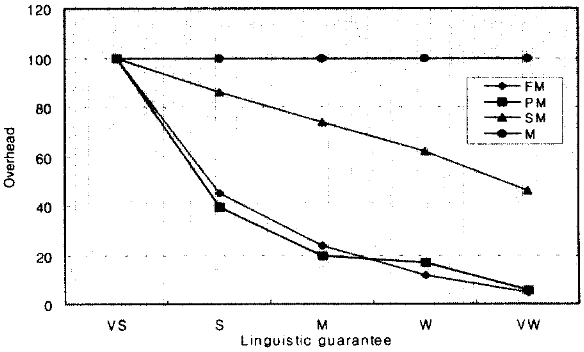
Let the mobile network is based on the hexagonal cell model where one neighboring cell exists at every $\pi/3$ in $0 \le \theta < 2\pi$ (see (figure 3)). The number of neighboring cells on a cell, nc is 6, where the neighboring cell which is adjacent to $0 \le \theta < \pi/3$ is called the 1-st neighboring cell, the neighboring cell which is adjacent to $\pi/3 \le \theta < 2\pi/3$ is called the 2-nd neighboring cell, and so on.

We made 200 times of handoffs in the simulation, then simulation results are analyzed and evaluated by 150 times of handoffs from the 51-st handoff to the 200-th handoff. The performance of the fuzzy multicast scheme is evaluated by the bandwidth overhead of multicast scheme given as in equation (8).

$$Overhead = \frac{T_m}{T_c} \times \frac{nc_m}{nc} \times 100 \tag{8}$$

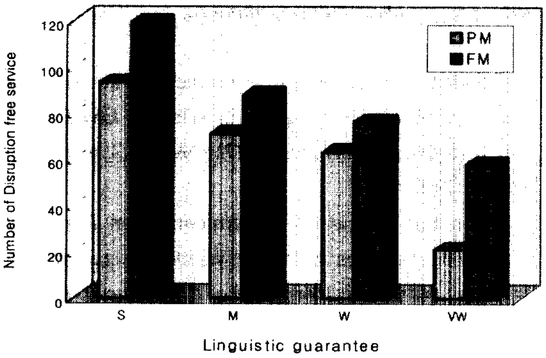
$$\text{where,}\quad T_m = \sum_{i=1}^{N-h} t_{m_i},\ nc = 6 \times N_h \text{ and } nc_m \sum_{i=1}^{N_h} |NC_{m_i}|.$$

(Figure 7) shows the performance of the multicast schemes according to linguistic guarantee for disruption free service. In the case that the linguistic guarantee is VS, it is known that the performance of the *fuzzy multicast* (FM) is equal to that of the *multicast* (M) and the *staggered multicast* (SM). However, in the other cases of linguistic guarantee, the performance of FM is better than that of M and SM. Also, we show that our performance and the performance of the probabilistic multicast (PM) are much the same, but



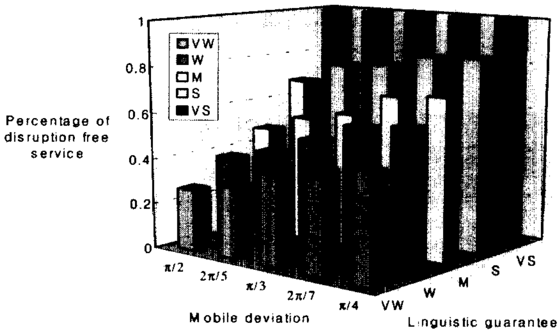
(Figure 7) The overhead of multicasts according to linguistic guarantee: $v = 900 \pm 225\,m/\min$, $sd = \pi/3$, $R = 300\,m$

the number of guarantees of our method is much more than that of the PM (see (Figure 8)). In the simulation of PM, the probability corresponding to linguistic guarantee is getting from defuzzifier equation (5). Therefore, the fuzzy multicast significantly reduces static network bandwidth usage, also provides better QoS than PM for the same degree of linguistic guarantee.



(Figure 8) The comparison of the number of disruption free services between FM and PM according to linguistic guarantee

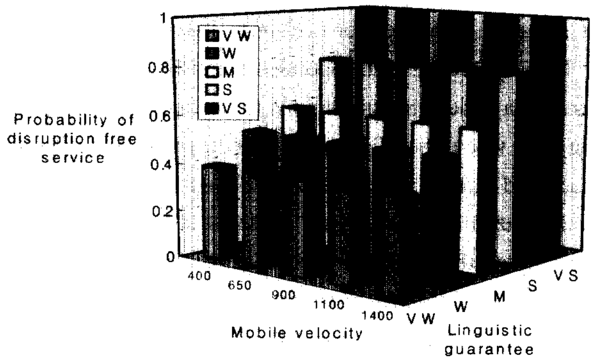
(Figure 9) shows the probability of disruption free service according to both linguistic guarantee and mobile deviation. From this figure, we know that linguistic guarantee is getting better and mobile deviation is getting smaller, the probability of disruption free service is getting higher. In the case that linguistic guarantee is the same, we confirm that the maximum difference among probabilities of disruption free service according to mobile deviations is 0.23. Also, in the case that mobile deviation is the same, we confirm that the maximum difference among probabilities of disruption free service according to linguistic guarantees is 0.73.



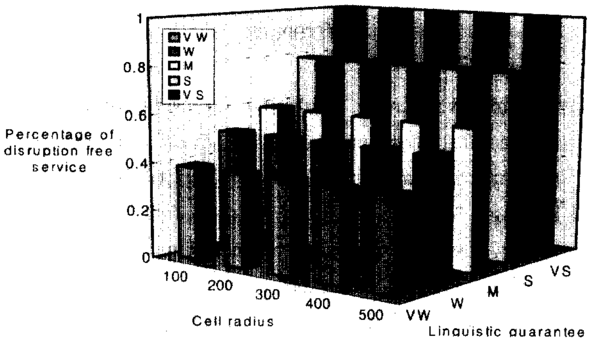
(Figure 9) Probability of disruption free service according to linguistic guarantee and mobile deviation: $v = 900 \pm 225\ m/min,\ R = 300\ m$

(Figures 10) and (Figures 11) show the probabilities of disruption free service according mobile velocity and cell radius, respectively. From these figures, we know that the probability of disruption free service doesn't change by mobile velocity and cell radius because cell latency T_h is adjusted dynamically by both mobile velocity (v) and cell radius (R) (see equation (3)). Also, we confirm that the maximum difference among the probability of disruption free service according to linguistic guarantees is 0.61.

As a result of QoS evaluations, it is known that the disruption free service is affected by both linguistic guarantee and mobile deviation. Specially, the degree of disruption free service is affected primarily by linguistic guarantee of a mobile user. Therefore, the fuzzy multicast can provide differential services with linguistic guarantee for disruption free service.



(Figure 10) Probability of disruption free service according to linguistic guarantee and mobile velocity: $sd = \pi/3,\ R = 300\ m$



(Figure 11) Probability of disruption free service according linguistic guarantee and cell radius: $sd = \pi/3,\ v = 900 \pm 225\ m/min$

6. Conclusion

There are various applications that provide the quality of service required by the users in mobile networks. The number of cells may become insufficient to provide the required quality of service because of the increment of service requests and the mobility of users. Cell splitting can then be used to increase the traffic handled in an area without increasing the bandwidth of the system. The reduction in the cell size cause an increment in the number of handoffs, thereby increasing the signaling traffic due to the handoff protocol messages. In addition, handoff also causes a disruption in service if it is not done in a fast and efficient manner.

In this paper, we propose the fuzzy multicast that provides a linguistic guarantee for disruption free service despite handoffs occurred during an active connection. The fuzzy multicast estimates the velocity and the direction for a mobile host and forecasts the cell latency. Then, the fuzzy multicast determines basic fuzzy set for each neighboring cell using membership function, composes the multicast group for the MH using control rules, and computes a multicast time using the defuzzifier of linguistic guarantee for disruption free service.

Then, according to the specified linguistic guarantee for a user, data packets are transmitted to the forecasted neighboring cells where the MH will be handoff potentially, after the staggered time. From the simulation results, the performance of the fuzzy multicast is better than that of both the multicast method and the staggered multicast method. Also, the fuzzy multicast provides better QoS than the probabilistic multicast for the same degree of linguistic guarantee. Therefore, the fuzzy multicast significantly reduces the static network bandwidth usage and also efficiently provides differential services according to a linguistic guarantee for disruption free service.

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