A New Mobility Management Scheme for Third-Generation Mobile Communications

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Abstract: The key issue of mobility management scheme in third-generation mobile system is to reduce the load of HLR, and to eliminate the system bottleneck. A new scheme is presented in this paper, based on HomeVLR technology. The location update and call delivery are processed in local HomeVLR, so that the load of HLR is distributed to all VLR's in the area, with little impact on call setup delay and little increase in VLR's load.

I. INTRODUCTION

One of the main research fields on personal communication is Mobility Management. By the developing of third-generation mobile communication system, mobility management scheme with high performance becomes one of the key issues to improve service quality of system. At present, researches on mobility management can be classified into two main categories. The first group studies database technology, network structure and cell structure [1,2]. The second group studies statistical characters of user mobility and service model [3,4].

In this paper, we present a new mobility management scheme based on HomeVLR (HVLR).

II. HVLR SCHEME

In this paper, we introduce the conception of HomeVLR. Each VLR is also a HomeVLR. Besides his permanent HLR, each mobile subscriber also has a HVLR and VLR in the HA where he is visiting. HLVR reserves the same user service data as those in his HLR. All location update and call connection in this HA are controlled by his HVLR, so that HVLR works like the HLR in second-generation network. When the subscriber leaves the HA, a new HVLR in new HA will be assigned to him. The assignment of HVLR can be executed when subscriber moves across the HA border or when he turns on his mobile station. In order to balance the service load between HVLR's in HA border areas and those in central areas, some kinds of allocation algorithm or network management protocol can be used to distribute HVLR in HA evenly.

Location update is described as below:

(a) MS enters HA and sends "Location Update"(Loc_Upd) to VLR. VLR assigns an HVLR to this MS (according to specific algorithm, HVLR can be the same as VLR or another VLR)

(b) VLR sends "Location Update Request" (Loc_Upd_Req) to HVLR.

(c) HVLR sends "Location Update Confirmation" (Loc_Upd_Cnf) to VLR

(d) HVLR sends "Location Cancellation" (Loc_Canc) to previous VLR of the MS

(e) If it is the first time to assign an HVLR to the MS or HVLR of the MS changes, new HVLR will inform MS's HLR and HLR will inform the previous HVLR. At any time, HLR will reserve current HLVR pointer of the MS

(f) When MS updates location later, step b – step d will be repeated.

Call connection setup is described as below:

(a) MS1 sends "Call Setup" (Cc_Setup) to VLR1.

(b) VLR1 inquires MS2's HLR for MS2's MSRN.

(c) HLR sends "Call Forwarding" (Call_Fwd) to

HVLR of MS2

(d) HVLR requests MS2's MSRN from VLR2 (Msrn_Req)

(e) VLR2 returns MSRN to HVLR (Msrn_Cnf)

(f) HVLR returns MSRN to VLR1 (Msrn_Ack)

(g) VLR1 sets up connection to VLR2 by MSRN

III. SYSTEM MODEL AND ANALYSIS

1. Basic Assumptions

In order to simplify analysis, we make these assumptions: the processing procedures of location update and call connection in VLR and HLR are decomposed according to input messages. Only messages relating to data operation will be considered. "Loc_Upd_Cnf" and "Loc_Canc" will invoke the operation of storing and deleting user service profile, so they will be considered as individual input. Saving and updating HVLR pointer and deleting old HVLR pointer will only invoke little data operation, so they can be neglected in analysis. Call connection setup and the processing of "Msrn_Ack" in VLR don't invoke data operation, so they can also be neglected. When analyzing call connection setup, we only consider those procedures that both caller and callee are mobile subscribers. When caller and callee are in the same VLR, call connection can be setup directly, no HLR or HVLR will be involved.

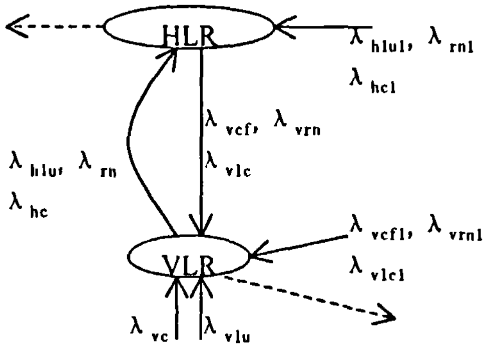

Fig. 1 System Model of 2G Network

We also make these assumptions. Subscribers are distributed evenly in the system. A HA includes n VLR's (LA's). We assume Passion arrival in the input of the system. HLR is assumed to have an infinite buffer and single exponential server with the average service rate μ_h. Also VLR is assumed to have an infinite buffer and single exponential server with the average service rate μ_v. λ_v and λ_h represent total arrival rate at VLR and HLR respectively. Let Pm represents the probability that caller and callee are in the same HA.

2. 2G Mobile System Model and Analysis

Second-generation System model is shown in Fig. 1. Average arrival rate of message "Loc_Upd", "Loc_Upd_Cnf", "Loc_Canc" and "Msrn_Req"at VLR is λ_{vlu}, λ_{vcf}, λ_{vlc} and λ_{vrn}. At VLR, arrival rates of messages "Loc_Upd_Cnf", "Msrn_Req" and "Loc_Canc" from external HLR's are λ_{vcf1}, λ_{vrn1} and λ_{vlc1} respectively. Call arrival rate at VLR is λ_{vc}. At HLR, arrival rate of the call from local VLR (controlled by the HLR) is λ_{hc}. Arrival rate of message "Loc_Upd_Req", "Msrn_Cnf" at HLR is λ_{hlu}, λ_{rn}. At HLR, arrival rate of messages "Loc_Upd_Req", "Msrn_Cnf" and incoming call from external VLR's are λ_{hlu1}, λ_{rn1} and λ_{hc1} respectively. Processing of message "Msrn_Ack" at VLR doesn't include database operation, thus such messages can be excluded from the input message queue in analysis. So, we have

$$\lambda_v = \lambda_{vlu} + \lambda_{vc} + \lambda_{vcf} + \lambda_{vlc} + \lambda_{vrn} + \lambda_{vcf1} + \lambda_{vlc1} + \lambda_{vrn1} \quad (1)$$

$$\lambda_h = \lambda_{hlu} + \lambda_{rn} + \lambda_{hc} + \lambda_{hlu1} + \lambda_{rn1} + \lambda_{hc1} \quad (2)$$

Consider the whole system, we have [6]

$$\lambda_{vcf} + \lambda_{vcf1} = \lambda_{vlu} \quad (3)$$

$$\lambda_{vlc} + \lambda_{vlc1} = \lambda_{vlu} \quad (4)$$

The probability that caller and callee are in the same VLR is Pm/n. So, The leaving rate relating to λ_{vc} is

$$\lambda_{vrn} + \lambda_{vrn1} = (1 - \frac{P_m}{n})\lambda_{vc} \quad (5)$$

$$\lambda_{hlu} + \lambda_{hlu1} = n\lambda_{vlu} \quad (6)$$

$$\lambda_{hc} + \lambda_{hc1} = \lambda_{rn} + \lambda_{rn1} = n(1 - \frac{P_m}{n})\lambda_{vc} \quad (7)$$

So

$$\lambda_v = 3\lambda_{vlu} + (2 - \frac{P_m}{n})\lambda_{vc} \quad (8)$$

$$\lambda_h = \lambda_{rn} + \lambda_{rn1} = n\lambda_{vlu} + 2(n - P_m)\lambda_{vc} \quad (9)$$

Thus, average system times (queuing time plus service time) at VLR and HLR are

$$W_{v2} = \frac{1}{\mu_v - \lambda_v} = \frac{1}{\mu_v - 3\lambda_{vlu} - (2 - \frac{P_m}{n})\lambda_{vc}} \quad (10)$$

$$W_{h2} = \frac{1}{\mu_h - \lambda_h} = \frac{1}{\mu_h - n\lambda_{vlu} - 2(n - P_m)\lambda_{vc}} \quad (11)$$

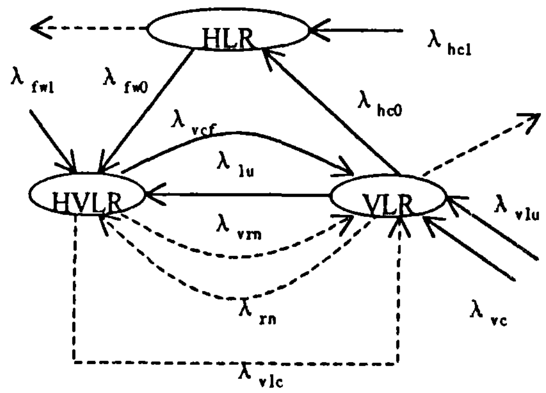

Fig. 2 System Model of HVLR Scheme

3. Analysis of HVLR Scheme

Fig. 2 shows the system model of HVLR scheme. Arrival rate of "Loc_Upd" at VLR is λ_{vlu}. Because of the local mobility of mobile subscriber, inter-HA location update and turn-on location update can be neglected. So "Loc_Upd_Req" should be sent to HVLR in local HA. Assume the arrival rate at HVLR is λ_{lu}. Arrival rate of "Loc_Upd_Cnf", "Loc_Canc" at VLR is λ_{vcf}, λ_{vlc}. Call arrival rate at VLR is λ_{vc}, part of such calls will be connected outside the HA. At HLR, call arrival rate from local and external VLR is λ_{hc0} and λ_{hc1}, arrival rates of "Call_Fwd" from local and external HLR are λ_{fw0} and λ_{fw1} respectively. Arrival rate of "Msrn_Req" at VLR is λ_{vrn}. Arrival rate of "Msrn_Cnf" at HVLR is λ_{rn}. Processing of "Msrn_Ack" at VLR doesn't invoke database operation, so those messages can be neglected. When caller and callee are in the same HVLR, MSRN can be directly requested, no HLR will be interrogated. So, we have

$$\lambda_v = \lambda_{vlu} + \lambda_{lu} + \lambda_{vcf} + \lambda_{vlc} + \lambda_{vc} + \lambda_{fw0} + \lambda_{fw1} + \lambda_{vrn} + \lambda_{rn} \quad (12)$$

$$\lambda_h = \lambda_{hc0} + \lambda_{hc1} \quad (13)$$

Considering the whole system, we have,

$$\lambda_{vlu} = \lambda_{lu} = \lambda_{vcf} = \lambda_{vlc} \quad (14)$$

The probability that caller and callee are in the same VLR is Pm/n. We have

$$\lambda_{vrn} = \lambda_{rn} = (1 - P_m / n)\lambda_{vc} \quad (15)$$

The probability that callee is in the VLR of caller or caller is in the HVLR of callee, is $P_s = P_m/n + P_m/(n-1)$. So,

$$\lambda_h = \lambda_{hc0} + \lambda_{hc1} = n \cdot (1 - P_s)\lambda_{vc} = n \cdot (1 - \frac{P_m}{n} - \frac{P_m}{n-1})\lambda_{vc} \quad (16)$$

$$\lambda_{fw0} + \lambda_{fw1} = \frac{1}{n}\lambda_h = (1 - P_s)\lambda_{vc} \quad (17)$$

$$\lambda_v = 4\lambda_{vlu} + (5 - \frac{4P_m}{n} - \frac{2P_m}{n-1})\lambda_{vc} \quad (18)$$

So, average system times (queuing time plus service time) at VLR and HLR are

$$W_{v3} = \frac{1}{\mu_v - \lambda_v} = \frac{1}{\mu_v - 4\lambda_{vlu} - (5 - \frac{4P_m}{n} - \frac{2P_m}{n-1})\lambda_{vc}} \quad (19)$$

$$W_{h3} = \frac{1}{\mu_h - \lambda_h} = \frac{1}{\mu_h - n \cdot (1 - \frac{P_m}{n} - \frac{P_m}{n-1})\lambda_{vc}} \quad (20)$$

IV. Numerical Example and Conclusions

According to (11) and (20), HVLR scheme reduces average system time in HLR. In order to get numerical results, we use the same values of system parameters as those in [7],

$$\lambda_{vlu} = \frac{390 \times 30.3 \times 5.6}{3600 \times \pi} = 5.85 / s$$

$$\lambda_{vc} = \frac{1.4 \times 57.4 \times 390}{3600} = 8.70 / s$$

We assume n=128, P_m=0.8, μ_v=1000/s, so we have

$$W_{v2} = 1.04\times10^{-3}s, W_{v3} = 1.07\times10^{-3}s$$

$$\frac{W_{v3}}{W_{v2}} = 102\%$$

Fig. 3 shows the values of average system time in HLR of second-generation network and HVLR scheme, against average service rate of HLR. It shows that HVLR scheme reduces the average system time in HLR greatly when average service rate is relatively low. When μ_h=4000/s, we have

$$W_{h2} = 0.98\times10^{-3}s,\ W_{h3} = 0.35\times10^{-3}s$$

$$\frac{W_{h3}}{W_{h2}} = 35.7\%$$

From the analysis, we can conclude that HVLR scheme can greatly reduce the processing load in HLR, at the same time, processing load in VLR only has a very slight increase. HVLR scheme can be looked as a kind of local distributed database of related subscriber coming from whole system, which inherit the merit of distributed mobility management scheme.

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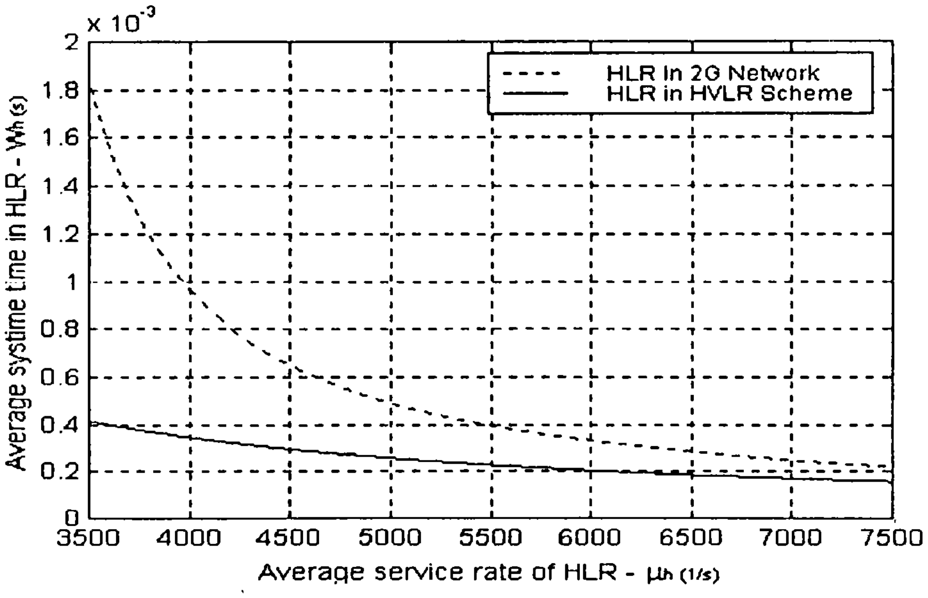

Fig. 3 Average System Time in HLR