Implicit Deregistration in 3G Cellular Networks

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Abstract— **In a 3G cellular network, the visitor location registers (VLRs), the gateway location registers (GLRs), and the home location registers (HLRs) form a three-level mobility database structure. When users leave a GLR/VLR service area, deregistration with a GLR/VLR is required. Deregistration may create significant traffic in the network, especially the traffic between a GLR and a HLR, which is the remote/international traffic. In this paper, we propose a hierarchical implicit deregistration scheme with a first/subsequent registration in 3G cellular networks to effectively eliminate deregistration traffic. An analytic model is proposed to carry out the performance of the proposed scheme. Our study shows that the proposed scheme not only reduces the local deregistration traffic between the GLR and the VLR, but also reduces the remote/international deregistration traffic between the HLR and the GLR. This is especially true when the ratio of the cost of the remote/international traffic between the GLR and the HLR to the cost of local traffic between the VLR and the GLR is high.**

Keywords- Home location register, Registration.

I. INTRODUCTION

The ANSI-41 [1] and GSM (Global System for Mobile communication) MAP (Mobile Application Part) [2] have been standardized to support mobility management in second generation (2G) wireless cellular networks. Both ANSI-41 and MAP use a two-tier system of home (HLR) and visited (VLR) location databases. The HLR database is used to record mobile users' information. The service area is partitioned into several location areas (LAs). Every LA is associated with a mobility database called the VLR, which is used to record mobile users' temporary location information when a mobile user enters the visited LA. Registration is the process by which mobile phones inform the network of their current locations. Deregistration is the process by which mobile phones inform the network to delete their record in the old VLR when they move out of a LA so that the reclaimed storage can be used by other mobile phones.

In ANSI-41 [1] and GSM MAP [2], explicit deregistration schemes are used for registration and deregistration processes. In explicit deregistration schemes, the registration process ensures that a mobile phone's registration in a new VLR causes deregistration in the old VLR. However, in such schemes, both registration and deregistration may result in significant amount of network signaling traffic. In [3], we proposed an implicit deregistration scheme that totally eliminates the deregistration traffic. In this scheme, the record of a mobile phone is not deleted from the VLR when the mobile phone leaves that LA. If a mobile phone arrives at a LA and the VLR is full, a random record is deleted, and the reclaimed storage is reassigned to the new arriving mobile phone. When a call arrives and the call's record is missing in the VLR, the call is lost.

In order to reduce the international roaming signaling traffic, the GLR within the UMTS (Universal Mobile Telecommunication System) Core Network is proposed in specification 3GPP 23.119 [1]. The GLR is a node between a VLR and the HLR. It handles location management of roaming subscriber in visited network without involving the HLR. Deregistration of the GLR may also result in significant amount of network signaling traffic. The cost of deregistration of the GLR is much more expensive than that of deregistration of the VLR since the traffic between the GLR and the HLR is remote/international traffic.

In this paper, we propose a hierarchical implicit deregistration scheme with a first/subsequent registration in 3G cellular networks to effectively eliminate deregistration traffic, especially the traffic involving remote/international calls. In the proposed scheme, the record of a mobile phone is not deleted from the GLR/VLR when the mobile phone leaves that the GLR/VLR service area. If a mobile phone arrives at the GLR/VLR service area and the GLR/VLR is full, a random record is deleted, and the reclaimed storage is reassigned to the new arriving mobile phone. If a call arrives and the call's record is missing in the GLR/VLR, a first or subsequent registration is executed to restore the GLR/VLR record before the call setup operation proceeds.

II. MOBILITY MANAGEMENT IN UMTS

In 3G networks with GLR, at the first location update procedure, the subscriber information is downloaded from the HLR to the GLR. The GLR handles *Update Location* messages from the VLRs as if it is the HLR of the subscribers at the subsequent location updating procedures. The GLR enables the procedure invisible from the home network so that this hierarchical location management can reduce the inter-network signaling for location management. The GLR keeps the information until receiving *Cancel Location* (same as deregistration) message from the HLR. The call origination procedure sets up a call initiated by a mobile user using the VLR record. The first registration is handled by the HLR and the VLR via the GLR. For all subsequent registration

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operations, the HLR is no longer involved, and the operations are performed locally between the VLRs and the GLR.

Algorithm I. First Registration

Step 1 (First Registration Request)

Step 1.1. The mobile phone (a_1) sends a registration request.
Step 1.2. The VLR creates a temporary VLR record for a_1.
Step 1.3. The VLR sends an Update *Location* message to the GLR.
Step 1.4. The GLR creates a temporary GLR record for a_1 and stores the VLR Number and serving MSC Number.
Step 1.5. The GLR sends an Update *Location* message to the HLR with the GLR Number as *VLR* Number, and IM-MSC (Intermediate-MSC) Number as MSC Number.

Step 2 (First Registration Response)

Step 2.1. The HLR stores the GLR Number and IM-MSC Number from received message as respectively VLR Number and serving MSC Number.
Step 2.2. The HLR initiates insert subscriber data procedure and cancel location procedure in Algorithm III.
Step 2.3 When the GLR receives *Insert Subscriber Data* message from the HLR, the GLR stores the subscriber's information in the message and transport it to the VLR.

Step 3 (First Registration Acknowledgement)

The HLR acknowledges the *Update Location* message from the GLR and the GLR transports the acknowledgement to the VLR.

Algorithm II. Subsequent Registration

Step 1.When the GLR receives an Update *Location* message from newly visited VLR and it holds the subscriber information, the GLR stores the new VLR Number and new MSC Number.
Steps 2-5. The GLR initiates insert subscriber data procedure and cancel location procedure in Algorithm III.
Step 6. The GLR acknowledges to the *Update Location* message.

Algorithm III. Location Cancellation

Step 1. The newly visited VLR sends an Update *Location* message the HLR after the MS left the network with the GLR.
Step 2. The HLR sends the *Cancel Location* message to the GLR.
Step 3. The GLR transports this *Cancel Location* message to the previously visited VLR.
Step 4. The old VLR deletes the user's record, and sends response.
Step 5. After receiving the response, the GLR transports the response to the HLR and delete the roamer's subscriber profile and location information.
Step 6. The HLR initiates insert subscriber data procedure to the newly visited VLR.
Step 7. The newly visited VLR acknowledges the HLR's insert subscriber data procedure.
Step 8. The HLR acknowledges the newly visited VLR's *Update Location* message.

Algorithm IV. Call Origination

Step 1. The mobile phone sends the call origination request
Step 2. The MSC forwards the request to the VLR.
Step 3. The VLR checks the profile and grants the call request.
Step 4. The MSC sets up the trunk according to the standard SS7 call setup procedure as in 2G wireless systems.

III. HIERARCHICAL IMPLICIT DEREGISTRATION

When the implicit registration is used, the record of a mobile phone is not deleted from the GLR/VLR when the mobile phone leaves that the GLR/VLR service area. If a mobile phone arrives at the GLR/VLR service area and the GLR/VLR is full, a random record is deleted, and the reclaimed storage is reassigned to the new arriving mobile phone. If a call arrives and the call's record is missing in the GLR/VLR, a first or subsequent registration is executed to restore the GLR/VLR record before the call setup operation proceeds. To implement the implicit deregistration, we propose the following VLR/GLR algorithms I', II', and IV'. Notice that the Location Cancellation Algorithm is eliminated.

Algorithm I': First Registration

Step 1 (First Registration Request)

Step 1.1. Step 1.1 in Algorithm I is executed.
Step 1.2. If the VLR is not full, Step 1.2 in Algorithm I is executed. Otherwise, a randomly chosen record is deleted, and the reclaimed storage is reassigned for a_1.
Step 1.3. Step 1.3 in Algorithm I is executed.
Step 1.4. If the GLR is not full, Step 1.4 in Algorithm I is executed. Otherwise, a randomly chosen record in the GLR (with equal probability) is deleted, and the reclaimed storage is reassigned for a_1 and stores the VLR ID and serving MSC ID.
Step 1.5. Step 1.5 in Algorithm I is executed.

Step 2 (First Registration Response)

Step 2.1. Step 2.1 in Algorithm I is executed.
Step 2.2. The HLR initiates insert subscriber data procedure, however, the location cancellation procedure will not be initiated.
Step 2.3. Step 2.3 in Algorithm I is executed.

Step 3 (First Registration Acknowledgement)

Step 3 in Algorithm I is executed.

Algorithm II': Subsequent Registration

Step 1.

Step 1.1. The mobile phone (a_1) sends a registration request to the VLR. If the VLR is full, it creates a temporary VLR record for a_1. Otherwise, a randomly chosen record (with equal probability) is deleted, and the reclaimed storage is reassigned to a_1. The VLR sends a *Location Update* message to the GLR.
Step 1.2. When the GLR receives a *Location Update* message from the newly visited VLR and if it holds the subscriber information for the user, the GLR stores the new VLR ID and the new serving MSC ID. Otherwise, a randomly chosen record (with equal probability) is deleted, the reclaimed storage is reassigned to a_1 and stores the VLR ID and the serving MSC ID, and Step 1.5 and Step 2 in Algorithm I' are executed.

Steps 2-5.

The GLR initiates the insert subscriber data procedure, however location cancellation procedure will not be initiated.

Step 6. Step 6 in Algorithm II is executed.

Algorithm IV': Call Origination

Steps 1-2. Steps 1-2 in Algorithm IV are executed.
Step 3. If both the VLR and the GLR find the user's record, Step 3 in Algorithm IV is executed and the algorithm proceeds to Step 4. Otherwise, the mobile phone initiates the Subsequent Registration Algorithm II' and Algorithm IV is executed. In this case, the algorithm exits without executing Step 4.
Step 4. Step 4 in Algorithm IV is executed.

IV. AN ANALYTICAL MODEL

We observe that in 3G wireless networks, the signaling traffic between the HLR and the GLR is usually remote/international with high cost, whereas the signaling traffic between the GLR and the VLR is usually local with low cost. We will study the performance issues of the record-missing probability for both the GLR and the VLR, and the gains from the traffic reduction between the HLR and GLR (the international/remote traffic) and between the GLR and the VLR (local traffic). To do so, we invoke the following assumptions: **(a)** the residence time τ_1 of a user in a LA follows a general probability distribution with probability density function $f_m(\tau_1)$, the mean $1/\eta$, the Laplace transform $f^*(s) = \int_{\tau_1=0}^{\infty} f(\tau_1) e^{-s\tau_1} d\tau_1$, and the probability distribution function $F(\bullet)$; **(b)** the call arrivals to a user form a Poisson process with the call arrival rate λ. Let τ_2 be the call interarrival time.

Let N be the number of users in a LA, K be the number of VLRs connected to a GLR, M be the size of a VLR, and L be the size of a GLR. From assumption (a), if N is sufficiently large, we can approximate the arrivals of mobile phones into a VLR by a Poisson process with rate $N\eta$ [4, 6]. Moreover, the net call arrivals to the mobile phones in the VLR form a Poisson process with rate $N\lambda$ [4, 6]. Similarly, we can approximate the arrivals of mobile phones into the GLR by a Poisson process with rate $KN\eta$, and the net call arrivals to the mobile phones in the GLR by a Poisson process with rate $KN\lambda$. If the VLR record replacement is done randomly with equal probability, the probability that a VLR record is not selected for replacement is

$$q_V = (M-1)/M \tag{1}$$

Similarly, if the GLR record replacement is done randomly with equal probability, the probability that a GLR record is not selected for replacement is

$$q_G = (L-1)/L \tag{2}$$

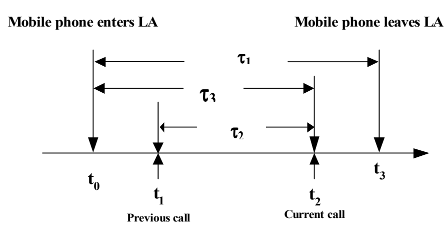

Fig. 1. The timing diagram of mobile phone P and its calls

Fig. 1 shows the timing diagram for a mobile phone P that enters a LA at time t_0, and leaves the LA at time t_3. τ_1 is P's residence time in the LA. Assume that a call to P arrives at time t_2 where $\max(t_0, t_1) < t_2 < t_3$, and the previous call to P arrives at time t_1. We do not assume that $t_1 > t_0$. Let $\tau_1 = t_3 - t_0$, $\tau_2 = t_2 - t_1$, $\tau_3 = t_2 - t_0$ and $\tau = \min(\tau_3, \tau_2)$. We notice that τ_2 is the call interarrival time, both τ_1 and τ_2 had already defined in assumptions (a) and (b). Since the Poison call arrivals are random observers to P's residence time, following the residual life theorem [7], τ_3's density function is

$$r_m(\tau_3) = \eta \int_{t=\tau_3}^{\infty} f_m(t) = \eta[1 - F_m(\tau_3)] \tag{3}$$

Let $R_m(\bullet)$ be the distribution function of $r_m(\bullet)$ and the Laplace transform for τ be $f^*(s)$. We have,

$$f(\tau) = \int_{t_2=\tau}^{\infty} \lambda e^{\lambda\tau_2} r_m(\tau) d\tau_2 + \int_{\tau_3=\tau}^{\infty} \lambda e^{\lambda\tau} r_m(\tau_3) d\tau_3 = e^{\lambda\tau}\{r_m(\tau) + \lambda[1 - R_m(\tau_3)]\} \tag{4}$$

$$f^*(s) = \int_{\tau=0}^{\infty} e^{-s\tau} f(\tau) d\tau = \left[\lambda s + \lambda^2 + \eta s(1 - f_m^*(\lambda + s))\right]/(s+\lambda)^2 \tag{5}$$

Let e_V denote the event that that when a call to a mobile phone P arrives, the VLR record r_V of P does not exist. Let $P(e_V)$ denote the probability that the event e_v occurs. $P(e_V)$ is called the record-missing probability for the VLR.

Let e_G denote event that when a call to a mobile phone P arrives (P is in one of the VLRs in the GLR), the GLR record r_G of P does not exist. Let $P(e_G)$ be the probability that the event e_G occurs. $P(e_G)$ is called the record-missing probability for the GLR.

Note that P has records in both the GLR and the VLR at times t_0, t_1, and t_2, since the records are potentially restored either by a forced first-registration (at t_0) or by a forced subsequent registration (at t_0, t_1, and t_2). Before t_0, t_1, and t_2, P's records in both the GLR and the VLR may not exist if the records are replaced due to the hierarchical implicit deregistration. On the other hand, P's records in either the VLR or the GLR may be replaced during the period $[\max(t_0, t_1), t_2]$, if either a forced first/subsequent registration or a call setup for another mobile phones selects P's record in either the VLR or in the GLR for replacement during this period. This period is τ. Notice that even though P's record in the VLR is not replaced, P's record in the GLR may still be replaced. On the other hand, if P's record in the VLR is replaced, P's record in the GLR may not be replaced.

When a call to a mobile phone P arrives at t_2, P's record in the VLR is replaced in the period τ either by a forced first/subsequent registration or by a call request to another mobile phone whose VLR record does not exist. The replacement rate due to the forced registration is $N\eta$ and the replacement rate due to call requests is with rate $P(e_V)N\lambda$. The latter statement is obtained as follows: since $N\lambda$ is the rate for call arrivals to mobile phones in the VLR, $P(e_V)N\lambda$ is the rate of call requests for which the corresponding VLR records do not exist. We also notice that P's record in a VLR is selected for replacement with probability $1 - q_V$. Let X_V be the number of such operations in period τ that may cause the replacement of a VLR record. Then, the rate of operations that may cause the replacement of a VLR record is given as follows:

$$\lambda_V^* = (\eta + P(e_V)\lambda)N = \left(\frac{\eta + P(e_V)\lambda}{1 - q_V}\right)\left(\frac{N}{M}\right) \tag{6}$$

Similarly, when a call to a mobile phone P arrives at t_2, P's record in the GLR is replaced in the period τ either by a forced first/subsequent registration (with rate $KN\eta$) or by a call request to another mobile phone whose GLR record does not exist (with rate $P(e_G)KN\lambda$). Again, the latter statement is obtained as follows: $KN\lambda$ is the rate for call arrivals to mobile phones in the GLR, $P(e_G)KN\lambda$ is the rate of call requests for which the corresponding GLR records do not exist. Moreover, the P's record in the GLR is selected for replacement with probability $1-q_G$. Let X_G be the number of such operations in the period τ, leading to the replacement of a GLR record. Then, the rate of operations that may cause the replacement of a GLR record is

$$\lambda_G * = (\eta + P(e_G)\lambda)KN = \left(\frac{\eta + P(e_G)\lambda}{1-q_G}\right)\left(\frac{KN}{L}\right) \tag{7}$$

X_V and X_G are two Poison random variables with the probability mass functions [7]

$$P[X_V = n] = \frac{(\lambda_V * \tau)^n}{n!} e^{-\lambda_V * \tau} \tag{8}$$

$$P[X_G = n] = \frac{(\lambda_G * \tau)^n}{n!} e^{-\lambda_G * \tau} \tag{9}$$

Since $f*(s)$ is analytic in the right complex plane by observation, from (4) and power series expansions, the record-missing probabilities $P(e_V)$ and $P(e_G)$ can be expressed as

$$P(e_V) = 1 - \int_{\tau=0}^{\infty} \left\{ \sum_{n=0}^{\infty} q_V{}^n P[X_V = n] \right\} f(\tau) d\tau \tag{10}$$
$$= \frac{A_V{}^2 + \lambda A_V - \eta A_V[1 - f_m*(A_V+\lambda)]}{(A_V+\lambda)^2} \text{ where } A_V = \lambda_V * (1-q_V)$$

$$P(e_G) = 1 - \int_{\tau=0}^{\infty} \left\{ \sum_{n=0}^{\infty} q_G{}^n P[X_G = n] \right\} f(\tau) d\tau \tag{11}$$
$$= \frac{A_G{}^2 + \lambda A_G - \eta A_G[1 - f_m*(A_G+\lambda)]}{(A_G+\lambda)^2} \text{, where } A_G = \lambda_G * (1-q_G)$$

Both $P(e_V)$ (with (6) and (10)) and $P(e_G)$ (with (7) and (11)) can be computed by the following iterative algorithms. Let the pair ($P(e)$, $\lambda *$) stand for either the pair ($P(e_V)$, $\lambda_V *$) or the pair ($P(e_G)$, $\lambda_G *$).

Step 1. Select the initial value for $P(e)$.

Step 2. Compute $\lambda *$ based on (6) or (7).

Step 3. Let $P(e)_{old} \leftarrow P(e)$.

Step 4. Compute $P(e)$ based on (10) or (11).

Step 5. Let δ be a predefined small value. If $|P(e) - P(e)_{old}| < \delta |P(e)|$, then exit. Otherwise, $P(e)_{old} \leftarrow P(e)$ and go to step 2.

The above iterative algorithm has been extensively used and validated by many experiments [6]. We can easily show that the above algorithm converges to the unique solution $P(e_V)$ or $P(e_G)$, and the convergence is exponentially fast.

For a VLR, let μ_{V1} be the saved deregistration traffic between the GLR and the VLR in the hierarchical implicit deregistration scheme and μ_{V2} be the extra traffic created between the GLR and the VLR due to the forced first/subsequent registrations. Then, we have $\mu_{V1} = N\eta$ and $\mu_{V2} = P(e_V)N\lambda$. Similarly, for a GLR, let μ_{G1} be the saved deregistration traffic between the HLR and the GLR in the hierarchical implicit deregistration scheme and μ_{G2} be the extra traffic created between the HLR and the GLR due to the forced registration. Similarly, we have $\mu_{G1} = KN\eta$ and $\mu_{G2} = P(e_G)KN\lambda$. Let α_V be the ratio of a deregistration cost to a registration cost for the VLR, and α_G be the ratio of a deregistration cost to a registration cost for the GLR. In a typical mobile phone network, we have $1<\alpha_V<2$ and $1<\alpha_G<2$ [4]. Let σ be the traffic cost ratio of the remote/international traffic cost between the GLR and HLR versus the local traffic between the VLR and the GLR. Normally, we expect that σ >>1. The saved remote traffic γ_{remote}, the saved local traffic γ_{local}, and the saved total traffic γ in the hierarchical implicit deregistration scheme for a GLR with K associated VLRs are given as follows

$$\gamma_{remote} = \sigma[\mu_{G1} - \alpha_G \mu_{G2}] = KN[\sigma\eta - P(e_G)\alpha_G\lambda] \tag{12}$$

$$\gamma_{local} = K[\mu_{V1} - \alpha_V \mu_{V2}] = KN[\eta - P(e_V)\alpha_V\lambda] \tag{13}$$

$$\gamma = \gamma_{remote} + \gamma_{local} = KN\left[(\sigma+1)\eta - \left(P(e_G)\alpha_G + P(e_V)\alpha_V\right)\lambda\right] \tag{14}$$

V. Numerical Results

In this section, we carry out the performance analysis for the hierarchical implicit deregistration scheme with forced first/subsequent registration. We further assume that the LA residence times have a Gamma density function with mean $1/\eta$ and variance ν [4]. The Laplace transform for the Gamma LA residence time distribution is

$$f_m*(s) = \left[1/(1+\eta\upsilon s)\right]^{1/(\eta^2\upsilon)} \tag{15}$$

Therefore, (10)-(11) can be rewritten as

$$P(e_V) = \frac{A_V{}^2 + \lambda A_V - \eta A_V[1 - (1+\eta\upsilon A_V + \eta\upsilon\lambda)^{-1/(\eta^2\upsilon)}]}{(A_V+\lambda)^2} \text{, where } A_V = \lambda_V * (1-q_V) \tag{16}$$

$$P(e_G) = \frac{A_G{}^2 + \lambda A_G - \eta A_G[1 - (1+\eta\upsilon A_G + \eta\upsilon\lambda)^{-1/(\eta^2\upsilon)}]}{(A_G+\lambda)^2} \text{, where } A_G = \lambda_G * (1-q_G) \tag{17}$$

Based on (6) and (16), we can calculate $P(e_V)$ using the iterative algorithm introduced in the previous section. Similarly, we can calculate $P(e_G)$ based on (7) and (17). Then, we can calculate γ_{remote}, γ_{local}, and γ using the values of $P(e_V)$ and $P(e_G)$ based on (12)-(14). Based on γ_{remote}, γ_{local}, and γ, we investigate the performance of the hierarchical implicit deregistration with forced first/subsequent registration as follows.

Fig. 2 plots the saved total traffic γ against λ/η (the expected number of calls to a mobile phone when a mobile phone is in a LA). Here, we assume that $M=10000$, $N=3000$, $L=6000$, $\alpha_G=1$, $\alpha_V=1$, $\sigma=1.5$, 3.0, 5.0, and $\nu=0.1/\eta^2$, $1/\eta^2$, $10/\eta^2$ in the hierarchical implicit deregistration scheme for a GLR with 2 associated VLRs. The figure indicates that by exercising the hierarchical implicit deregistration, the portion of deregistration traffic can be significantly reduced, especially when σ is high. We expect σ higher when the traffic between the GLR and HLR is the international traffic. The figure also shows that the saved total traffic decrease as λ/η increases. That is, if the mobile phone's mobility is high or the call arrival rate is low, it is more likely that when a call arrives, the corresponding VLR record and GLR record have been replaced. Furthermore, the figure demonstrates how the variance ν of the Gamma cell residence time distribution affects the system performance with a fixed mean $1/\eta$: the saved total traffic in the hierarchical implicit deregistration decreases as ν increases.

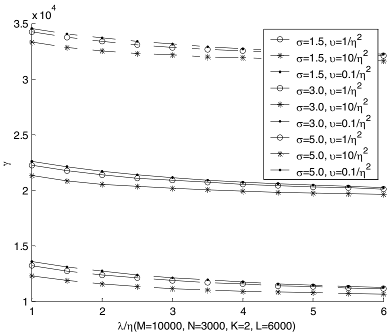

Fig. 2 Effects of σ, ν and λ/η on γ

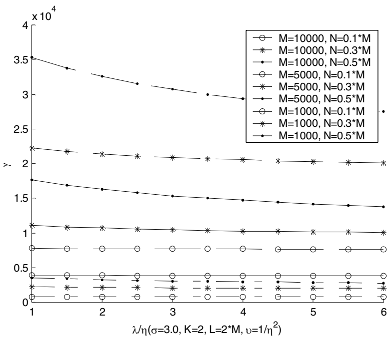

Fig. 3. Effects of *M, N*, and λ/η on γ

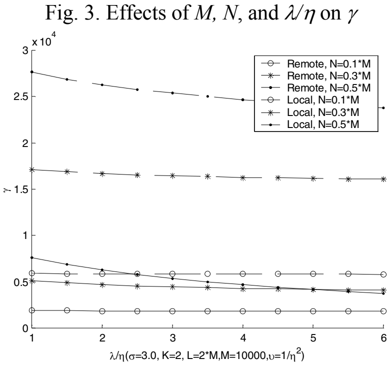

Fig. 4 The saved remote traffic vs. saved local traffic

Fig. 3 plots the saved total traffic γ against λ/η with $\sigma=3.0$, $L=2*M, \nu=1/\eta^2$, $\alpha_G=1$, $\alpha_V=1$, $M=10000, 5000, 1000,$ and $N=0.1M, 0.3M, 0.5M$ in the hierarchical implicit deregistration for a GLR with 2 associated *VLRs.* The figure shows that by exercising the hierarchical implicit deregistration, the portion of deregistration traffic can be significantly reduced, especially when *M* (the size of the VLR) is large. The saved traffic increases when *M* increases. The figure also shows that the saved total traffic increases significantly when *N/M* increases. Furthermore, the figure demonstrate that when *M* is large ($M\geq10000$) and *N/M* is large ($N/M\geq0.3$), the saved total traffic decreases as λ/η increases. That is, when both *M* and *N/M* are large, if the mobile phone's mobility is high or the call arrival rate is low, in which case, it is more likely that when a call arrives, the corresponding VLR record and the corresponding GLR record will be replaced. On the other hand, when *M* is small ($M<10000$) and *N/M* is small ($N/M<0.3$), the saved total traffic is insensitive as λ/η increases.

Fig. 4 plots the saved remote traffic γ_{remote} and the saved local traffic γ_{local} against λ/η with $\sigma=3.0$, $L=2*M, \nu=1/\eta^2$, $\alpha_G=1$, $\alpha_V=1$, $M=10000,$ and $N=0.1M, 0.3M, 0.5M$ in the hierarchical implicit deregistration for a GLR with 2 associated VLRs. The figure indicates that by exercising the hierarchical implicit deregistration, the portion of the saved remote traffic can be significantly larger than the saved local traffic, especially when *N/M* is large. Both the saved remote traffic and the saved local traffic increase when *N/M* increases.

VI. CONCLUSIONS

This paper proposes a hierarchical implicit deregistration scheme to reduce the signaling traffic due to deregistration in 3G wireless cellular systems. An analytical model is developed to evaluate the performance of the proposed scheme. The saved remote traffic, the saved local traffic, and the total saved traffic are used as the output performance measures. The study indicates that by exercising the hierarchical implicit deregistration, the portion of deregistration traffic can be significantly reduced, especially when the traffic cost ratio of the remote/international traffic cost between the GLR and HLR versus local traffic between the VLR and the GLR is high. Moreover, by exercising the hierarchical implicit deregistration, the portion of the saved remote traffic can be significantly larger than the saved local traffic. The portion of deregistration traffic can be significantly reduced, especially when the size of the VLR is large. The saved traffic increases when the size of the VLR increases. The total saved traffic increases dramatically when the ratio of the number of mobile phones to the size of the VLR databases increases. The results can be useful in mobility database dimensioning and QoS provisioning in 3G wireless network design.

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