Comparative Performance Analysis of Domain Name based Location Management

Abu S. Reaz, **Mohammed Atiquzzaman**
Telecommunications and Networks Research Lab
School of Computer Science, University of Oklahoma,
Norman, OK 73019-6151, USA.
Email: {sayeem_reaz,atiq}@ou.edu

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Abstract— **Mobility management in an IP network requires a Location Manager to identify the location of mobile host. Four mobility management schemes (SIGMA, Migrate, HIP and TCP-R) in the literature have proposed Domain Name Service as a location manager, with performance results available only for SIGMA. In this paper, we introduce a generic analytical model to compare the performance of DNS as location manager for all the four schemes. Our results shows that DNS is a feasible solution as location manager for all the four mobility management schemes; the performance, however, is better with SIGMA.**

I. Introduction

Mobility management consists of two fundamental operations: Handoff and Location Management. Handoff occurs when a mobile device changes its point of attachment while still continuing with the service that it has been providing. Location management refers to the task of locating (finding the IP address) a Mobile Host (MH) by a Correspondent Node (CN) in order to initiate and establish a connection.

Fig. 1 illustrates different steps of mobility management: (1) MH changes its subnet and obtains new IP address, (2) MH updates CN, and (3) LM is updated with new IP address.

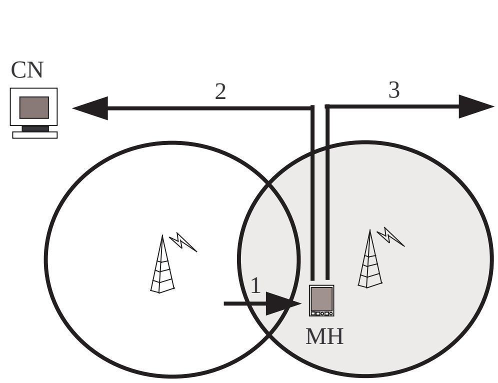

Fig. 1. Mobility and location management.

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In a layered network architecture for data communications, handoff management can be managed at different layers. For example, Mobile IP (MIP) [1] is a network layer based handoff management scheme from IETF, MSOCKS [2] is a transport layer solution, and IEEE 802.11b follows a Layer 2 solution for handoff. There are two common choices for implementing a Location Manager (LM) for the task of location management: 1) Dedicated Location Manager and 2)Domain Name System (DNS) [3]. The advantage of being able to deploy a LM without any change in the Internet infrastructure led us to investigate the suitability and performance of using DNS as a LM for mobility management for a generic mobility mobility management scheme.

The suitability and success of DNS as LM depends on how successfully it can locate a MH. Failure to provide the correct IP address of the MH results in a query failure. The success rate of a LM is determined by the fraction of queries that result in a successful connection to the MH avoiding query failure.

One of the earliest suggestions on using directory server for location management can be found in [4]. But it does not discuss implementation technique in a real world scenario. A recent proposal [5] discusses the use of DNS as location management but lacks performance evaluation and consideration of challenges, such as *query failure* involved in using DNS as a LM. Atiquzzaman et al. [6] lists different transport layer mobility management schemes that propose to use DNS as LM without giving any detail. In our previous works [7], [3], we analyzed the performance of DNS as LM using mathematical analysis for different mobility models for a particular mobility management scheme: Seamless IP diversity based Generalized Mobility Architecture (SIGMA) [8]. In these two works, we showed how suitable DNS is for location management based on cell residence time and random waypoint mobility model. There are, however, three more mobility management techniques that also propose to use DNS for location management. They are Migrate [5], TCP-Redirection [9], and Host Identity Protocol (HIP) [10]. We extend our previous work [7], [3] and discuss the relative implementation and performance analysis of DNS as LM for different schemes.

We introduce a generic analytical model that compares the performance DNS as LM for four different mobility management schemes. This is significantly different from previous works, as results of this paper focus on relative performance analysis based on common parameters instead of analysis within the context of a single scheme. The *authors are not aware of any (including the above mentioned ones) previous study* on comparative performance evaluation of DNS as a LM for different mobility management schemes in mobile data networks. The *objective* of this paper is to analyze and compare the performance of DNS as a LM for SIGMA, HIP, TCP-R, and Migrate; based on success rate which takes into account the overlapping distance of two neighboring subnets, latency in the network, radius of the subnet and the residence time of MH in that subnet. Our *contributions* in this paper are (i) comparing the performance of DNS for four mobility management schemes based on an analytical model, and (ii) identifying the impact of MH velocity and network delay on query failure for different handoff techniques.

The result of our analysis shows that even though the performance of DNS varies with handoff technique DNS can be used as LM with a high success rate irrespective of the mobility scheme.

The rest of the paper is organized as follows. Sec. II describes the deployment of DNS as a LM for he different mobility management schemes, Sec. III develops the analytical model for evaluation of DNS as a LM. Sec. IV shows results on performance of DNS as LM, followed by conclusions in Sec. V.

II. DNS and Location Management

Domain Name System represents a hierarchy of servers including Authoritative Name Server (ANS) that serves name to address mapping and Local Name Server (LNS) maintained at local networks that caches this mapping for a certain period of time (called Time To Live (TTL)) as indicated by the corresponding ANS for faster resolution of future queries.

A. Deployment of DNS as LM

In a mobile network, where MH is changing its IP address and updating DNS continuously, all the name lookup queries should be served by the ANS. Any non-zero TTL value suggested by an MH would make the ANS to instruct a querying LNS to cache the mapping for that TTL value and any new local request within that TTL period would be served by that LNS. But by that time MH might change its address again resulting in query failure. Therefore, TTL values at the ANS should be *zero* for all the MHs.

Challenges in deploying DNS as LM include higher traffic load on DNS which is insignificant with today's hardware advancement and safe delivery of update packets which is ensured through secure update proposed in [11].

The most significant challenge is during the handoff period. As shown in Fig. 2, when CN queries for IP address of MH (1) and in the meantime MH moves to new subnet and obtains new IP address (2), the query reply (3) gives incorrect address. MH updates the LM (4) but the connection request (5) comes to an out of use IP address and ends up in failure. The effect

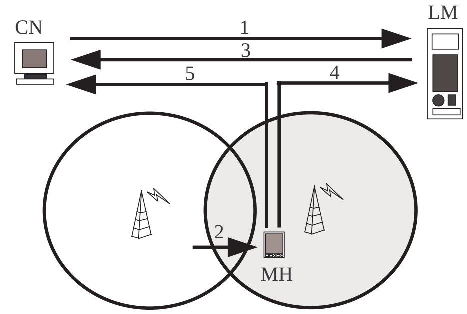

Fig. 2. Obtaining out-of-date address by the CN.

of the above issue is minimized when the handoff process is based on IP diversity, as in SIGMA, which enables an MH to have two IP addresses and maintain two data streams during the handoff period. In that case, if a connection request arrives *within* the overlapping zone, *even after the handoff*, the CN would be able to locate the MH with old IP address.

B. DNS as Location Manager for SIGMA

In this section, we will illustrate the use of DNS as LM for an IP diversity based (e.g. SIGMA [8]) handoff. During the residence of the MH in the overlapping area, the DNS record corresponding to a MH contains two IP addresses of the MH, and the DNS serves both the IP addresses in response to a location query. The order in which the IP addresses are stored in the DNS record determines the priority of the IP addresses, i.e. the sequence to be used by the CN to address the MH for connection setup.

Fig. 3 shows the sequence of updates to the ANS by the MH. When the MH reaches the boundary of the overlapping area of the two subnets, it obtains a new IP address (time t_1) and sends an update message to the ANS that stores the new address along with the old one in the DNS, with higher priority being assigned to the old IP address. Later on, when the MH hands off based on relative signal qualities of the two access points (time t_2), it sends another update message with the new IP address as the first address followed by the old IP address. When the MH leaves the overlapping area (time t_3), it sends an update to the ANS to remove the old IP address.

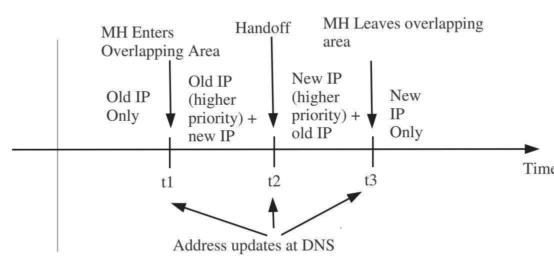

Fig. 3. MH's IP addresses in different stages of Handoff and their respective DNS updates.

C. DNS as Location Manager for Migrate

Migrate [5] uses Migrate TCP [5] that supports reconnection by allowing to recognize TCP connection initiation message as a part of an already established connection after being terminated for handoff. When an MH establishes a new connection with a CN via Migrate TCP, they exchange a token specific to that particular connection. When MH moves to a new subnet, after handoff, MH gets a new IP address and the existing Migrate TCP connections is terminated. Then, instead of establishing a new connection, MH puts the token in the initiation message which allows the CN to reestablish the previous connection. The MH runs a user level daemon program that detects whenever the MH changes its attachment point. Thus, after obtaining the new IP address, through that daemon, MH sends a secure dynamic update to DNS to make sure all the subsequent request is served with the new IP address from DNS.

D. DNS as Location Manager for HIP

HIP [10] *does not* use DNS directly as a LM, instead it uses another network entity called Rendezvous Server (RVS) which is a specially designed LM for continuous update and supposed to serve better than DNS [12]. HIP uses DNS to serve the IP address of the RVS. Whenever MH changes its point of attachment, MH notifies the RVS and RVS updates the record for that MH with the new IP address. For any name lookup, DNS serves the IP address of RVS and the Host Identifier Tag (HIT) to the CN. Then using HIT, CN sends the connection initiation message (HIP I1) to RVS. RVS knows the current IP address of MH and forwards I1 to MH. And MH replies to CN with the initiation acknowledgement (HIP I2) and all the subsequent communication is done between the CN and MH. Thus, for comparative analysis, we can assume that *RVS is a lightweight version of DNS* and maps HIT with IP address instead of domain name.

E. DNS as Location Manager for TCP-R

TCP Redirection [9] is a transport layer end-to-end mobility management technique. For TCP, each connection is uniquely identified using the pair of address specific to the two ends. Whenever MH moves into the coverage of a new subnet, it obtains a new address. Instead of establishing a new connection, TCP-R simply changes the IP address in already existing connections with the new one and continues with the connections. The new address is updated at the DNS using dynamic secure update.

F. Comparison

Fig. 4 compares and contrasts the use of DNS as LM for the above mentioned mobility management schemes described in earlier in this section. This figure shows MH, CN, DNS and Core Router required for all four schemes and RVS required for HIP. It also shows the different messages exchanged for location lookups and updates in all the schemes, each marked with a number. In the figure, messages 1 and 2 are applicable to all the schemes: querying the DNS server and receiving the IP address. Messages 3A and 3B are specific to HIP: sending HIP I1 message to RVS and forwarding HIP I2 to MH(Sec. II-D). Message 3 is for the rest of the schemes. Message 3R occurs specifically for SIGMA when CN tries to reach CN with second IP address if CN fails to contact MH using the first one. Message 4R is for HIP, when MH updates the RVS with new IP address after handoff. Messages 4A,B,C are for SIGMA, as described in Fig. 3. For TCP-R and Migrate, the only message is 4C: putting only the new IP address in DNS.

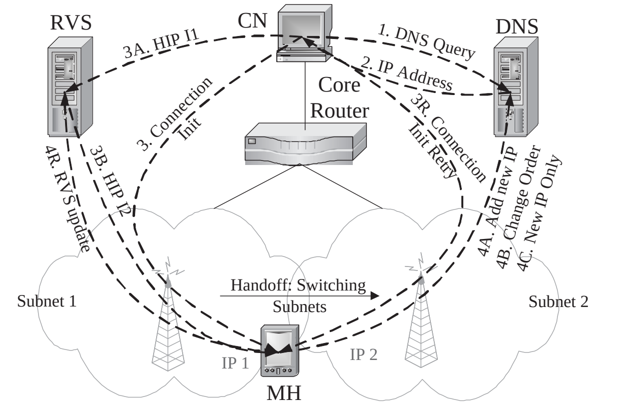

Fig. 4. Comparison of DNS as LM for different mobility management techniques

III. Analytical Model for Performance Evaluation of DNS as LM

The primary success measure of a DNS as LM is determined by how successfully it can provide the CN with the appropriate address such that the connection establishment request can be sent to the current address of the MH. We define success rate as the fraction of queries successfully served out of the total number of queries. In order to find success rate, in Sec. III-B, we derive the residence time of a MH in a subnet, in Sec. III-C, we derive the critical time during which location queries carries a possibility of failure, and in Sec. III-D we compute success rate based on traffic arrival rate to LM during its residence time and critical time.

A. Calculation of Residence Time

The primary success measure of a DNS as LM is how successfully it can provide the CN with the appropriate address such that the connection establishment request can be sent to the current address of the MH. We define success rate (Sec. III-D) as the fraction of queries successfully served out of the total number of queries. Success rate is represented by fraction of time where DNS might serve incorrect address, termed as the critical time (Sec. III-C), out of the total residence time (Sec. III-B).

B. Calculation of Residence Time

Mobile host moves according to Random Waypoint model [13], which is the most frequently used model in mobile networking research. In this mobility model, an MH randomly selects a destination point in the topology area according to uniform distribution, then moves towards this point at a random speed again uniformly selected between (v_{min}, v_{max}). One movement is called an *epoch*, and the elapsed time and the moved distance during an epoch are called *epoch time* and *epoch length*, respectively. At destination point, the MH will stay stationary for a period of time, called *pause time*, after that a new epoch starts.

Let,

$E(T)$ = expected value of *epoch time*.

$E(P)$ = expected value of MH pause time between movements.

$E(L)$ = expected value of *epoch length*.

$E(C)$ = expected number of subnet crossings per *epoch*.

v = moving speed of MH.

The objective of this section is to find the average residence time (T_{sub}^{res}) for MH in a subnet. which can be estimated by the time between two successive movements (*epoch time* plus *pause time*) divided by the number of subnet crossings during this epoch, as shown in Eqn. (1):

$$T_{sub}^{res} = \frac{E(T) + E(P)}{E(C)} \tag{1}$$

We first compute $E(T)$, since *epoch length* L and movement speed v are independent:

$$E(T) = E(L/v) = E(L)E(1/v) \tag{2}$$

Substituting epoch time, pause time and subnet crossing from Eqns. (2) into Eqn. (1), we can get the expression for T_{sub}^{res}. Reaz et al. [3] showed in detail the derivation and evaluation of T_{sub}^{res}.

C. Calculation of Critical Time

For analytical tractability, we make the simplifying assumption that all the queries are processed at the ANS without any referrals. For SIGMA, Migrate, and TCP-R, the process of communication initiation between a MH and CN has two parts. First the CN gets the Name to IP address mapping from the ANS, and then it initiates a connection with the MH with the IP as illustrated by the timeline in Fig. 5.

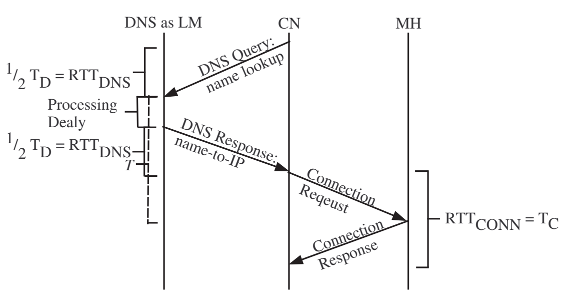

Fig. 5. Timeline of connection initiation from CN to MH.

For HIP, the CN initiates sends the initial HIP I1 to the RVS (Fig. 4), which forwards the packet to the MH as it knows the current location of MH. Then MH replies with response packet HIP I2 directly to the CN and all subsequent communication is done between CN and MH.

For SIGMA, we denote $\Delta t_{1+2} = t_2 - t_1$ and $\Delta t_{2+1} = t_3 - t_2$ as illustrated in Fig. 3. Here Δt_{1+2} is the time during which MH is in the overlapping area when the first address has a higher priority, i.e. before the handoff, and Δt_{2+1} is the time spent by MH in overlapping area when the new address has a higher priority, i.e. after the handoff. Let

$$\tau = \left(\frac{1}{2}\ T_D\right) + \left(\frac{1}{2}\ T_C\right) + T_S^d \tag{3}$$

Here $\frac{1}{2}\ T_D$ represents the time taken by the DNS name lookup reply to come from ANS to CN, $\frac{1}{2}\ T_C$ represents the time taken by the connection establishment request from CN to MH and, T_S^d is the query processing delay at ANS.

If the residence time of a MH in the overlapping area is $\Delta t_{1+2} + \Delta t_{2+1}$, for a DNS query to be successfully served with the current IP address of MH

$$\tau \leq (\Delta t_{1+2} + \Delta t_{2+1}) \tag{4}$$

For HIP, TCP-R and Migrate, when the MH hands over to a new subnet and gets a new IP address, during the time taken to update the LM, all the request served from LM will go to an incorrect IP address resulting failure.

In the Internet, the round trip delay is sum of round trip propagation delay, transmission delay and queuing delay. If

T_{CA}^d = Propagation delay between CN and ANS
T_{CM}^d = Propagation delay between CN and MH
T_{MR}^d = Propagation delay between MH and RVS
T_{MA}^d = Propagation delay between MH and ANS
β_{CA} = BW of the link between CN and ANS
β_{CM} = BW of the link between CN and MH
β_{MR} = BW of the link between MH and RVS
β_{MA} = BW of the link between MH and ANS
ψ_D = Avg. DNS query packet size
ψ_C = Avg. connection request packet size
$\bar{\xi}$ = Avg. queuing delay in the network
$\frac{1}{2}T_D = T_{CA}^d + \frac{\psi_D}{\beta_{CA}} + \bar{\xi}$
and $\frac{1}{2}T_C = T_{CM}^d + \frac{\psi_C}{\beta_{CM}} + \bar{\xi}$
Therefore,

$$\tau = T_{CA}^d + T_{CM}^d + \frac{\psi_D}{\beta_{CA}} + \frac{\psi_C}{\beta_{CM}} + 2\bar{\xi} + T_S^d \tag{5}$$

If the latency in the network increases, value of τ would increase and violate Eqn. (4). Then if $\tau > (\Delta t_{1+2} + \Delta t_{2+1})$,

$$T1_{cr}^S = (\tau - (\Delta t_{1+2} + \Delta t_{2+1})) \tag{6}$$

where any location query made within time $T1_{cr}^S$ would carry a possibility of failure. We call this period *Critical Time*.

Here an important assumption is that the time taken to update DNS ,Ψ, is not very large. So, for Eqn. (6) to hold, the DNS has to be updated before the MH leaves the overlapping region. Thus, the time taken to update a DNS record would be $T_{UD} = T_{MA}^d + \frac{\psi_D}{\beta_{MA}} + \bar{\xi} + \Psi$ and $T_{UD} > (\Delta t_{1+2} + \Delta t_{2+1})$ should be true. If this condition violates, than the MH would cross the overlapping distance and move into the new subnet before the DNS would have the new address. Thus, another measure of critical time for SIGMA would be

$$T2_{cr}^S = (T_{UD} - (\Delta t_{1+2} + \Delta t_{2+1})) \tag{7}$$

For Migrate, TCP-R and HIP, as they do not store multiple IP addresses in LM, the critical time would be the time taken to update the LM from MH. Any query within this time would actually be served with the incorrect IP address (Fig. 2). Thus, for these schemes, the sum of the time taken for an update message to travel to the LM and the time taken to update the LM is the critical time. So, for Migrate and TCP-R, critical time would be

$$T_{cr}^{M} = T_{UD} = T_{MA}^{d} + \frac{\psi_D}{\beta_{MA}} + \overline{\xi} + \Psi \tag{8}$$

As suggested in [12], we assume RVS is faster and more efficient than DNS. So for comparative analysis, we assume *RVS as a lightweight version of DNS*. Let, α be the ratio of the time taken to update RVS to the time taken to update DNS and γ is ratio of the RVS update packet size to DNS update packet size. Then, critical time for HIP is

$$T_{cr}^{H} = T_{MR}^{d} + \frac{\gamma\psi_D}{\beta_{MR}} + \overline{\xi} + \alpha\Psi \tag{9}$$

If d_{sub} is radius of a subnet and d_{ovr} is the overlapping distance, the asymptotic density function that gives the probability of the MH to be at a certain point on a line segment [0, d_{sub}] is given by $f_x(x) = -\frac{6}{{d_{sub}}^3}x^2 + \frac{6}{{d_{sub}}^2}x$ where x is any point on the line segment which basically reflects the distance of the MH from the center of the subnet [13]. Thus, Probability of a MH being within that subnet is $\int_0^{d_{sub}} f_x(x)dx = 1$ and Probability of the MH being in the overlapping zone is $\int_{x_{min}}^{d_{sub}} f_x(x)dx = 1 + 2\left(\frac{x_{min}}{d_{sub}}\right)^3 - 3\left(\frac{x_{min}}{d_{sub}}\right)^2$ where $x_{min} = d_{sub} - d_{ovr}$. Then if T_{ovr}^{res} is the residence time of MH in the overlapping zone, then $T_{ovr}^{res} = T_{sub}^{res}\int_{x_{min}}^{d_{sub}} f_x(x)dx$.

From Eqn. (3), essentially,

$$T_{ovr}^{res} = (\Delta t_{1+2} + \Delta t_{2+1}) = T_{sub}^{res}\int_{x_{min}}^{d_{sub}} f_x(x)dx \tag{10}$$

Network latency and residence time in the overlapping region, retrieved from Eqns. (5) and (10), can be evaluated in Eqn. (6) to get $T1_{cr}^{S}$. We can get $T2_{cr}^{S}$ from Eqns. (5) and (7). T_{cr}^{M} and T_{cr}^{H} can be found from Eqn. (8) and Eqn. (9), respectively, based on the network parameters.

D. Calculation of Success Rate

If T_{cr} is the critical time regardless of the mobility scheme, we can find the number of failures during a single handoff as E[$\chi(T_{cr})$], and total number of queries as $E[\chi(T_{sub}^{res})]$ where $\chi(t)$ represents number of queries within time t. If λ is the arrival rate of name lookup query to the LM, we have $E[\chi(T_{cr})] = \lambda T_{cr}$ and $E[\chi(T_{sub}^{res})] = \lambda T_{sub}^{res}$.

The success of DNS as a LM, depends on the fraction of time the DNS can successfully serve the right IP address in response to all the queries. So, Success Rate for SIGMA, ρ, can be defined as

$$\rho = \frac{E[\chi(T_{sub}^{res})] - E[\chi(T_{cr})]}{E[\chi(T_{sub}^{res})]} \tag{11}$$

Here, T_{cr} is $T1_{cr}^{S}$ and $T2_{cr}^{S}$ both for SIGMA, T_{cr}^{M} for Migrate and TCP-R and T_{cr}^{H} for HIP and can be obtained from Eqns. (6), (7), (8) and (9) respectively. Along with the value for critical time, we substitute residence time obtained from Eqn. (1) in Eqn. (11) to get the success rate.

IV. RESULTS

Eqn. (11) shows that the success rate for DNS as LM depends on residence time of MH in a subnet and the critical time. Critical time is dependant on the latency in the network, LM update time and the residence time of MH in the overlapping region. Residence time depends on subnet radius and mobile velocity. The success rate, therefore, depends on latency in the network, LM update time, velocity and overlapping distance between subnets.

One of the performance measures is the variation of the success rate as a function of overlapping distances for different network latencies. Assuming Eqn. (6) holds, for an average epoch length L = 300 meters, average MH velocity v = 20 m/sec, maximum pause time P_{max} = 10 sec, and for 10% of MHs changing subnet during an epoch (Eqn. (1)), a very high processing delay at server T_S^d = 3 sec, overlapping distance T_{ovr}^{res} = 40 meters, LM update time Ψ = 3 sec, and subnet radius d_{sub} = 500 meter, if network latency varies from 0.3 to 2.3 seconds, we found that for SIGMA, we have a success rate of one for latency 0.6 seconds or below. When latency increases to 2 seconds, the success rate for SIGMA, HIP and Migrate and TCP-R are 0.99, 0.98 and 0.975, respectively, as illustrated in Fig. 6.

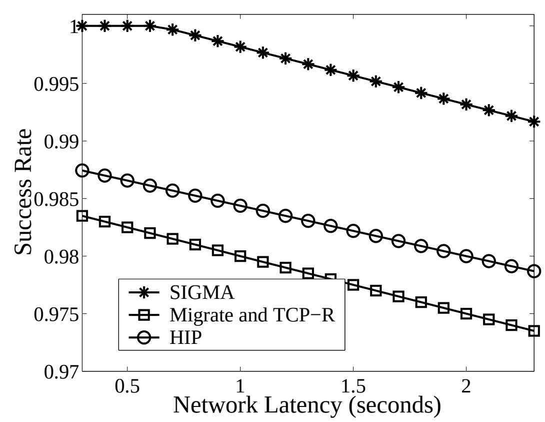

Fig. 6. Success rate against different network latency.

For the same configuration, if we have a fixed network latency of 0.5 sec, we see from Fig. 7 that for an overlapping distance over 40 meters, which is only 5% of the subnet diameter, the success rate for SIGMA settles to one but for the other schemes it remains constant, proving that we can improve the performance of DNS for SIGMA by increasing the overlapping distance, but not for the other schemes.

Another performance measurement variable is the residence time of MH in the subnet. How quickly an MH crosses a subnet and an overlapping region determines the residence time of MH in the subnet (T_{sub}^{res}) and in the overlapping

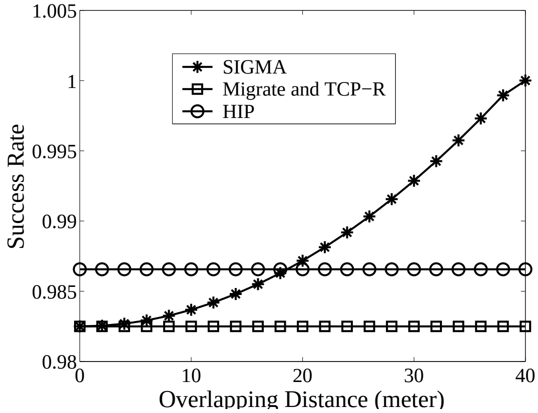

Fig. 7. Success rate against different overlapping area .

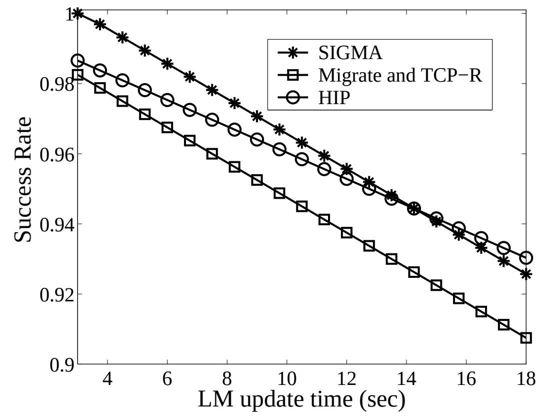

Fig. 9. Success rate against different LM update delay.

region (T_{ovr}^{res}), respectively. This is basically a function of MH velocity v. So, for a given latency of the 0.5 seconds in the network and $T_S^d = \Psi = 3$ sec, if the overlapping distance remains 40 meters and if v (Eqn **??**) varies from 10 m/sec to 60 m/sec, for $v \leq 20$ m/sec (20 m/sec = 72 km/hour), SIGMA can produce a success rate of one. But afterwards ρ goes towards 0.985 for SIGMA, 0.975 for HIP and 0.965 for Migrate and TCP-R, Fig. 8 shows change of success rate as a function of MH velocity.

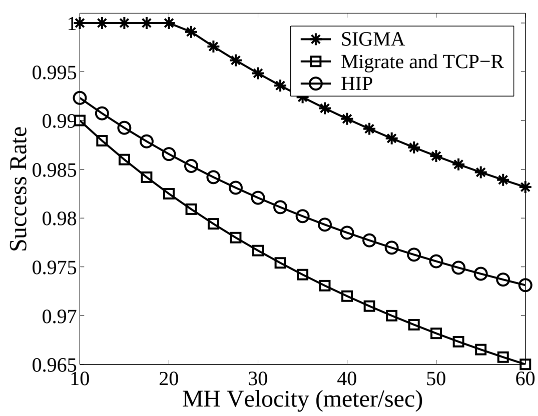

Fig. 8. Success rate against different MH velocity.

If Eqn. (6) does not hold, then the critical time for SIGMA is determined by Eqn. (7). For similar configuration described above, if $v = 20$ and Ψ varies from 3 sec to 18 sec, HIP performs best for a large update delay. Fig. 9 depicts the effect of LM update delay.

Thus, we deduce that within reasonable latency and overlapping region, DNS is able to serve as an LM successfully, with SIGMA having higher success rate than other schemes.

V. Conclusions

DNS has been considered as a Location Manager as it is already an established technology implemented in the Internet and is the originator of most of the connections. Previous studies have analyzed the performance of DNS as a location manager in the context of only one mobility management scheme in mobile data networks. As performance analysis of location manager is dependant on the location management scheme itself, in this paper, we introduced a relative performance analysis model and compared the performance of DNS as LM for four mobility management schemes. Our results clearly show that the performance of DNS as LM varies for different mobility schemes. For most of the cases, its works best with IP diversity based SIGMA but in case of high update delay at LM, HIP performs better. Thus, we conclude that DNS is a feasible solution for location management, irrespective of the mobility management technique, though it would perform better with IP diversity based scheme, SIGMA.

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