Comparative Performance Analysis of Domain Name based Location Management

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Abstract— **As domain name lookup is almost ubiquitous connection originator, Domain Name System (DNS) can be used for location management. The performance of DNS depends on the fraction of time it can successfully locate a mobile host. In this paper, we compare the performance of location management techniques for different mobility management schemes based on success rate which takes into account the radius of the subnet, the residence time of MH in that subnet, latency in the network and the overlapping distance of two neighboring subnets. Our analysis shows IP diversity based mobility management schemes are more suitable for domain name based location management and can serve with very high success rate even under some high network latency.**

I. INTRODUCTION

Increasing demand for mobility in wireless data network has given rise to various mobility management schemes. 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. 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. 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. Location management should be transparent to the CN, and it should provide a valid address to the CN.

There are two common choices for implementing a Location Manager (LM) for the task of location management.

1) Dedicated Location Manager: A dedicated location manager is deployed specifically to perform location management operations. The benefit of this system is it can borrow concepts from already mature cellular networks. However, it suffers from the disadvantage of requiring significant changes in the IP network infrastructure, which gives rise to deployment issues in the Internet.
2) Domain Name System (DNS): DNS [3] provides name to IP mapping for locating a host in the Internet. Since almost all connection establishments start with a name lookup, it is possible for a DNS to serve as a LM. DNS is already a part of the existing Internet infrastructure and supports dynamic secure updates [4]; the real benefit of this scheme is that no change in the Internet is required to deploy a location manager for mobile data hosts.

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 as illustrated in Fig. 1 for a generic mobility mobility management scheme.

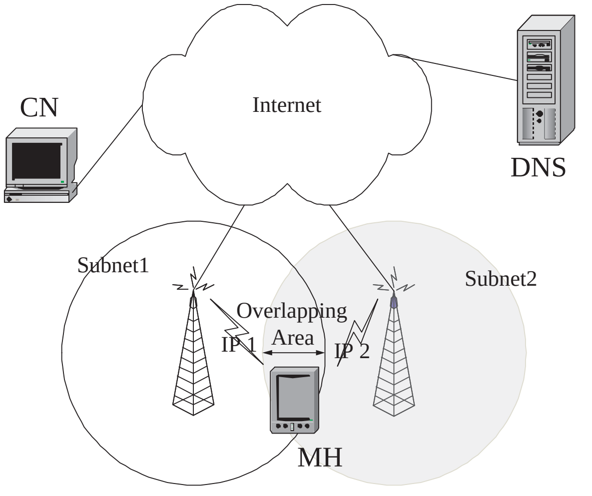

Fig. 1. DNS as a Location Manager.

The handoff process depends on the type of mobility management scheme used. However the handoff can be divided into two broad classes: soft or hard. *Soft handoff* (also called seamless handoff) permits a smooth handoff by allowing a mobile to communicate and exchange data with multiple interfaces, which is very common now a days for most of the systems, simultaneously during handoff. When a MH moves into the coverage of a new subnet, it obtains a new IP address while retaining the old one in the overlapping area of the two

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subnets. The MH communicates through the old IP address while setting up a new connection through the newly acquired IP address. When the signal strength of the old Access Point (AP) drops below a certain threshold, the connection is handed over to the new subnet and the new IP address is set to be the primary one. When the MH leaves the overlapping area, it releases the old IP address and only communicates over the new IP address. On the contrary, *hard handoff* results in disconnecting from the old access point when the signal strength is below a threshold before connecting to the new access point.

The suitability and success of DNS as LM depends on how successfully it can locate a MH. Location queries to the DNS and updating of DNS with location information of moving MHs cause control traffic which results in increased load on the DNS server. Moreover, failure to provide the correct IP address of the MH results in a query failure. In case of soft handoff, this type of failure can occur when a CN obtains an address from the LM, but the MH hands off to a new point of attachment when the connection request from the CN arrives at the MH. This is due to the network delay between the time a query is resolved and the time of a connection request to the CN. For the hard handoff, any when the MH hands off to the next subnet, it has only the new IP address and it needs to update DNS with the new address. Time taken to update DNS after the handoff is crucial as any name lookup query during this period would be served with wrong IP address and would lead to query failure. The success rate of a LM is determined by the fraction of queries that result in a successful connection to the MH.

One of the earliest suggestions on using directory server for location management can be found in [5]. It suggests a graph theoretic regional matching to provide cheap locality preserving representations for arbitrary networks. But it does not discuss implementation technique in a real world scenario. A recent proposal [6] discusses the use of DNS as location management but lacks performance evaluation and consideration of challenges, such as *query failure* and higher traffic load, involved in using DNS as a LM. Atiq et al. [7] lists different transport layer mobility management schemes that propose to use DNS as LM without giving any detailing. In our previous works, we analyzed the performance of DNS as LM using mathematical analysis in [8] and [9] using different mobility models for a particular mobility management scheme: Seamless IP diversity based Generalized Mobility Architecture (SIGMA) [10]. But there are three more prominent mobility management techniques that also propose to use DNS for location management. They are Migrate [6], TCP-Redirection [11], and Host Identity Protocol (HIP) [12]. 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 different mobility management schemes based on an analytical model, and (ii) identifying how the impact of MH velocity and network delay on query failure varies with different handoff techniques.

The result of our analysis shows the performance of DNS varies with handoff technique and how DNS serves the IP addresses. It indicates that within reasonable MH velocity and network latency, DNS can be used as LM with a high success rate irrespective of the mobility scheme. However, the LM performs better for IP diversity based scheme, SIGMA, than the other ones in most of the cases; though HIP is more capable of handling very high LM update time than SIGMA.

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 that includes 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

The basic functionalities that LM requires to have [13] are (i) *location update*: whenever an MH changes its point of attachment, it will register the new IP address with the ANS via dynamic secure update [4]; (ii) *location search*: as DNS is invariant and almost ubiquitous connection originator, all connection from a CN will initially go to the ANS for name lookup; (iii) *location search-update*: each lookup query will be served with the new IP address reflecting the new location of the MH and CN would retrieve updated address from ANS.

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 [4].

The most significant challenge is during the handoff period. As shown in Fig. 2, when the DNS server is updated (due to handoff) at t_2' just after the CN has completed a query at t_1', the address obtained by CN may no longer be valid. The CN may not be able to find the MH when it sends a connection request at t_3'. The effect of the above issue is minimized when the handoff process is based on IP diversity, as in SIGMA,

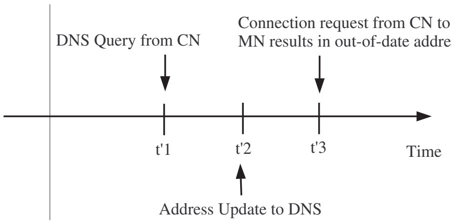

Fig. 2. Effect of obtaining out-of-date address by the CN.

which enables an MH to have two IP addresses and maintain two data streams during the handoff period. In that case, if the 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 [10]) 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.

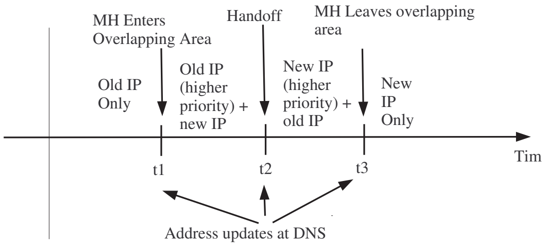

Fig. 3. MH's IP addresses in different stages of Handoff and their respective DNS updates.

C. DNS as Location Manager for Migrate

Migrate [6] is a transport layer mobility management scheme. As Migrate does not support IP diversity, the mobility has to be managed through hard handoff. Migrate proposes to use Migrate TCP [6] for its transport layer connection. Usually, when MH gets a new IP address, all the existing TCP connections would be terminated and need to be established again as new connections. But TCP Migrate allows to recognize TCP connection initiation message as a part of an already established connection, rather than requesting for a new connection. When an MH establishes a new connection with a CN, they exchange a token specific to that particular connection. When MH moves to a new subnet, it receives a new IP address and 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 would run a user level daemon program that would detect 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 [12] *does not* use DNS directly as a LM, instead it uses another network entity called Rendezvous Server (RVS) as LM. HIP uses DNS to serve the IP address of the RVS. The reason behind using RVS as LM instead of directly using DNS is RVS specially designed for continuous update and supposed to serve better than DNS [14]. As RVS does not change its address frequently, DNS is not required to be updated regularly. 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 (called 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 (called 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 [11] 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 existent connections with the new one and continues with the connections. The new address is updated at DNS using dynamic secure update.

F. Comparisons

Fig. 4 gives a compare and contrast illustration of the use of DNS as LM for the above mentioned mobility management schemes. In the figure, message 1 and 2 is common for all the schemes: querying the DNS server and receiving the IP address. Now, message 3A and 3B is specific to HIP: sending I1 message to RVS and forwarding it to MH (Sec. II-D). Message 3 is for the rest of the schemes. Message 3R would occur specifically for SIGMA when CN would try to reach CN with second IP address if CN fails to contact MH using the

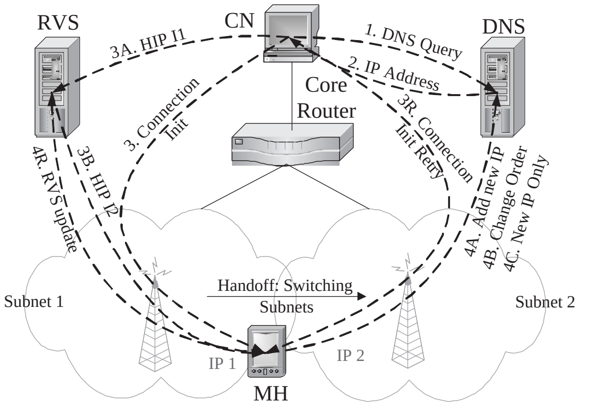

Fig. 4. Comparison of DNS as LM for different mobility management techniques

first one. Message 4R is for HIP, when MH updates the RVS with new IP address after handoff. Messages 4A,B,C is for SIGMA, as described in Fig. 3. For TCP-R and Migrate, the only message would be 4C: putting only the new IP address in DNS.

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 that, 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. That can be 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 [15], 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}). This 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:

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

Since the moving speed is of uniform distribution between (v_{min}, v_{max}), we have:

$$\begin{aligned} E(1/v) &= \int_{v_{min}}^{v_{max}} (1/v) \frac{1}{v_{max} - v_{min}} dv \\ &= \frac{\ln(v_{max}/v_{min})}{v_{max} - v_{min}} \end{aligned} \tag{3}$$

Where v_{min} and v_{max} is minimum and maximum values of v.

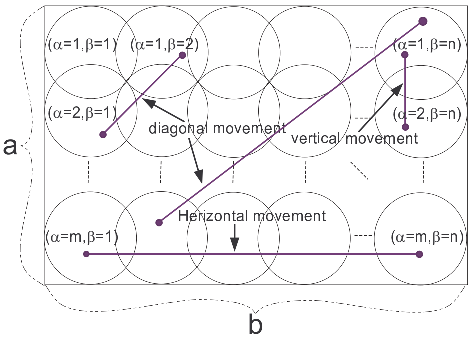

Fig. 5. Arrangement of subnets in a rectangular topology.

In order to determine $E(L)$ and $E(C)$, we assume an arrangement of circular subnets in a rectangular topology as shown in Fig. 5, where m, n are the number of vertically and horizontally arranged subnets in the topology, respectively. From [15], we know that $E(L)$ for a rectangular area of size $a \times b$ can be estimated as:

$$\begin{aligned} E(L) &= \frac{1}{15}\left[\frac{a^3}{b^2} + \frac{b^3}{a^2} + \sqrt{a^2+b^2}\left(3 - \frac{a^2}{b^2} - \frac{b^2}{a^2}\right)\right] \\ &+ \frac{1}{6}\left[\frac{b^2}{a}\Phi\left(\frac{\sqrt{a^2+b^2}}{b}\right) + \frac{a^2}{b}\Phi\left(\frac{\sqrt{a^2+b^2}}{a}\right)\right] \end{aligned} \tag{4}$$

$$\text{where} \quad \Phi(\cdot) = \ln\left(\cdot + \sqrt{(\cdot)^2 - 1}\right).$$

Now we can get epoch time $E(T)$ from Eqn.(2) using MH velocity and epoch length obtained from Eqns. (3) and (4). Since pause time has been assumed to be uniformly distributed between (0, P_{max}), we have:

$$E(P) = \int_0^{P_{max}} \frac{P}{P_{max}} dP = P_{max}/2 \tag{5}$$

Here P_{max} is the maximum pause time.

Next, we need to find $E(C)$, the general form of which can be expressed as [15]: $E(C) = \frac{1}{m^2n^2} \sum_{\alpha_j=1}^{m} \sum_{\beta_j=1}^{n} \sum_{\alpha_i=1}^{m} \sum_{\beta_i=1}^{n} C\begin{pmatrix} (\alpha_i, \beta_i) \\ (\alpha_j, \beta_j) \end{pmatrix}$

$C\begin{pmatrix} (\alpha_i, \beta_i) \\ (\alpha_j, \beta_j) \end{pmatrix}$ is the number of subnet crossings caused by one movement between subnet (α_i, β_i) to (α_j, β_j), which depends on the actual subnet shape and arrangement. Consider the circular subnet arrangement as shown in Fig. 5, we can observe three kind of movements: horizontal, vertical and diagonal. $C\begin{pmatrix} (\alpha_i, \beta_i) \\ (\alpha_j, \beta_j) \end{pmatrix}$ can be generalized by the following Manhattan distance metric:

$C\begin{pmatrix} (\alpha_i, \beta_i) \\ (\alpha_j, \beta_j) \end{pmatrix} = |\alpha_i - \alpha_j| + |\beta_i - \beta_j|$

So, we can get the expression for $E(C)$:

$$E(C) = \frac{1}{m^2n^2} \sum_{\alpha_j=1}^{m} \sum_{\beta_j=1}^{n} \sum_{\alpha_i=1}^{m} \sum_{\beta_i=1}^{n} (|\alpha_i - \alpha_j| + |\beta_i - \beta_j|) \tag{6}$$

Substituting epoch time, pause time and subnet crossing from Eqns. (2), (5) and (6) into Eqn. (1), we can get the expression for 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. 6.

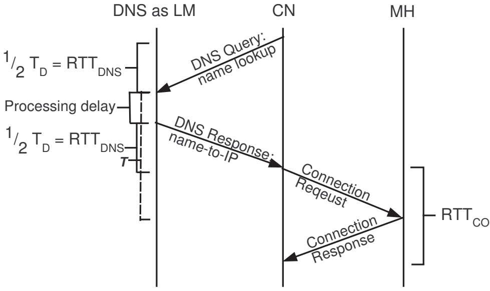

Fig. 6. Timeline of connection initiation from CN to MH.

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

For SIGMA, we denote $\Delta t_{1+2} = t_5 - t_4$ and $\Delta t_{2+1} = t_6 - t_5$ 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

$$\tau = \left(\frac{1}{2}\, T_D\right) + \left(\frac{1}{2}\, T_C\right) + T_S^d \tag{7}$$

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

$$\tau \leq (\Delta t_{1+2} + \Delta t_{2+1}) \tag{8}$$

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 would go to an incorrect IP address resulting failure.

Now, 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
$\overline{\xi}$ = Avg. queuing delay in the network
$\frac{1}{2}T_D = T_{CA}^d + \frac{\psi_D}{\beta_{CA}} + \overline{\xi}$
and $\frac{1}{2}T_C = T_{CM}^d + \frac{\psi_C}{\beta_{CM}} + \overline{\xi}$
Therefore,

$$\tau = T_{CA}^d + T_{CM}^d + \frac{\psi_D}{\beta_{CA}} + \frac{\psi_C}{\beta_{CM}} + 2\overline{\xi} + T_S^d \tag{9}$$

If the latency in the network increases, value of τ would increase and violate Eqn. (8). Then if $\tau > (\Delta t_{1+2} + \Delta t_{2+1})$,

$$T1_{cr}^S = (\tau - (\Delta t_{1+2} + \Delta t_{2+1})) \tag{10}$$

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 take to update DNS ,Ψ, is not very large. So, for Eqn. (10) 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 $T_{UD} = T_{MA}^d + \frac{\psi_D}{\beta_{MA}} + \overline{\xi} + \Psi$ 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

$$T2_{cr}^{S} = (T_{UD} - (\Delta t_{1+2} + \Delta t_{2+1})) \tag{11}$$

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

$$T_{cr}^{M} = T_{UD} = T_{MA}^{d} + \frac{\psi_D}{\beta_{MA}} + \bar{\xi} + \Psi \tag{12}$$

As suggested in [14], 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

$$T_{cr}^{H} = T_{MR}^{d} + \frac{\gamma\psi_D}{\beta_{MR}} + \bar{\xi} + \alpha\Psi \tag{13}$$

Now, 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 [15]. 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. (7), essentially,

$$T_{ovr}^{res} = (\Delta t_{1+2} + \Delta t_{2+1}) = T_{sub}^{res}\int_{x_{min}}^{d_{sub}} f_x(x)dx \tag{14}$$

Network latency and residence time in overlapping region retrieved from Eqns. (9) and (14) can be evaluated in Eqn. (10) to get $T1_{cr}^{S}$. We can get $T2_{cr}^{S}$ from Eqns. (9) and (11). T_{cr}^{M} and T_{cr}^{H} can be found from Eqn. (12) and Eqn. (13) 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 it can successfully serve the right IP address in response to all the queries. So, Success Rate for SIGMA, ρ, can be defined as

$$\rho = \frac{E[\chi(T_{sub}^{res})] - E[\chi(T_{cr})]}{E[\chi(T_{sub}^{res})]} \tag{15}$$

Here, T_{cr} is $T1_{cr}^{S}$ and $T2_{cr}^{S}$ for SIGMA, T_{cr}^{M} for Migrate and TCP-R and T_{cr}^{H} for HIP and can be obtained from Eqns. (10), (11), (12) and (13) respectively. Along with the value for critical time, we substitute residence time obtained from Eqn. (1) in Eqn. (15) to get the success rate.

IV. RESULTS

Eqn. (15) 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 varies different overlapping distances for different network latencies. Assuming Eqn. (10) 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 out that for SIGMA, we have success rate one for latency 0.6 seconds or below. When latency goes towards 2 seconds, the success rate for SIGMA, HIP and Migrate and TCP-R goes towards 0.99, 0.98 and 0.975 respectively as illustrated in Fig. 7.

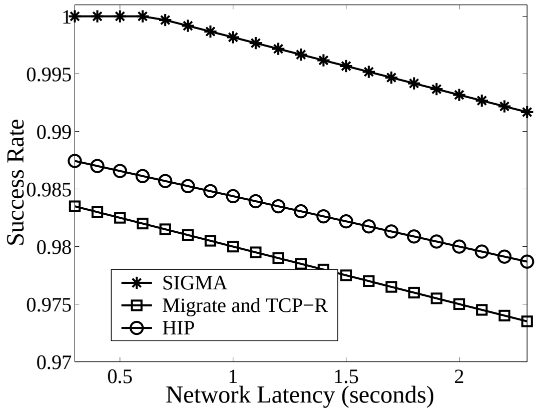

Fig. 7. Success rate against different network latency.

For the same configuration, if we have a fixed network latency of 0.5 sec, we see from Fig. 8 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

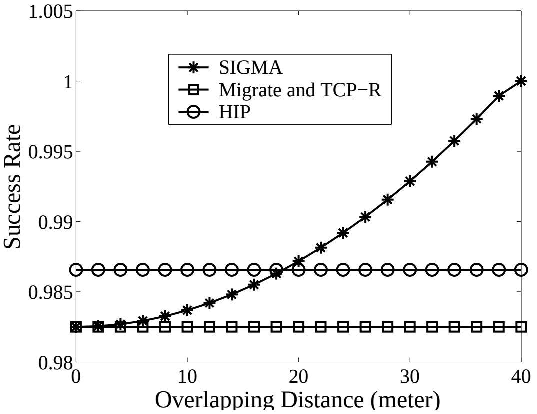

Fig. 8. Success rate against different overlapping area .

subnet and an overlapping region determines the residence time of MH in the subnet (T_{sub}^{res}) and in the overlapping 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 3) 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 the 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. 9 shows how success rate changes varying MH velocity.

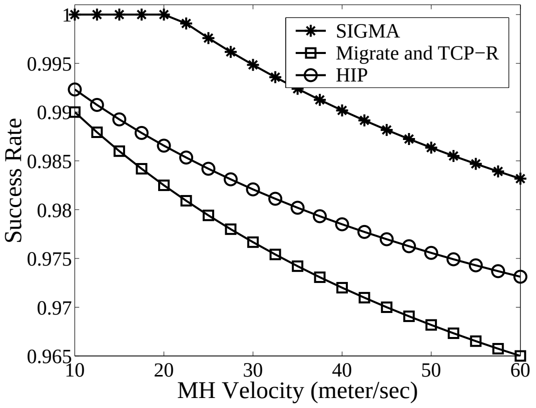

Fig. 9. Success rate against different MH velocity.

Now, if Eqn. (10) does not hold, then the critical time for SIGMA would be determined by Eqn. (11). 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. 10 depicts the effect of LM update delay.

Thus we deduce that within reasonable latency and overlapping region, DNS would be 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 in most of the connections. Previous studies have not analyzed the performance of DNS as a location manager in the context of different mobility management schemes in mobile data networks. In this paper, we compared the performance of DNS as LM for different mobility management schemes. Our results clearly shows that 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 to location management irrespective of the mobility management technique though it would perform better with IP diversity based scheme, SIGMA.

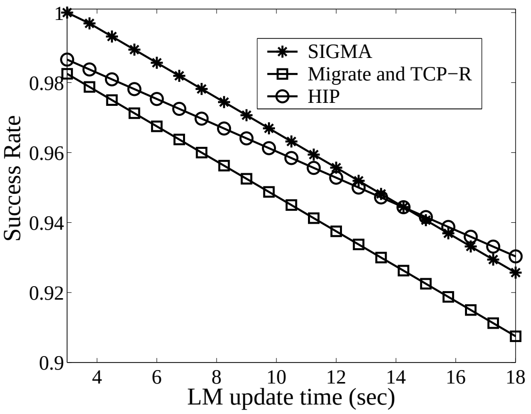

Fig. 10. Success rate against different LM update delay.

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