Performance of DNS as Location Manager

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Abstract— **Domain Name System (DNS) maps domain names to IP addresses in the Internet. DNS can, however, be used as a Location Manager (LM) for mobility management in wireless mobile networks. The suitability and performance of DNS as a LM for locating mobile hosts (MH) has not been studied in the past. In this paper, we develop an analytical model to measure the performance of DNS as LM for IP diversity based mobility management. We have used success rate, which takes into account the radius of the subnet, the residence time of a MH in a subnet, velocity of MH, network latency, DNS processing delay and the overlapping distance between two neighboring subnets as performance measures. Our analysis shows that for a reasonable overlap between cells, DNS can serve as a LM with very high success rate even under high network latency.**

I. INTRODUCTION

Mobility management in wireless data networks consists of two fundamental operations: Handoff Management 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 [3] 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 [4] 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 [5]; 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 transport layer based mobility management scheme based on IP diversity and soft handoff.

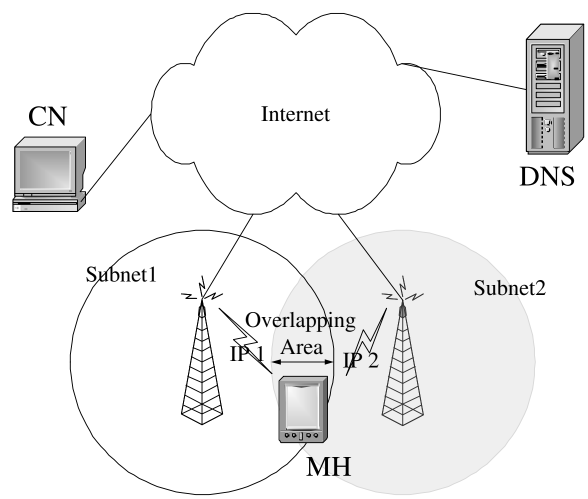

Fig. 1. DNS as a Location Manager.

During the handoff process, the MH has two IP addresses one for each of the neighboring subnets and communicates with both the APs at the same time with multiple interface card which is becoming common for mobile devices. This support for multiple IP address is called IP diversity, and our location management technique will be illustrated using Seamless IP diversity based Generalized Mobility Architecture (SIGMA) [6]. SIGMA is a new handoff management technique which exploits IP diversity offered by multiple interfaces in mobile devices. 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 subnets. The MH

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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. The duration of the MH in the overlapping area and the time during which the MH communicates over both IP addresses depend on the velocity of the MH and the power of the signals from the access points. Each time the MH handsoff to a new subnet, it updates the DNS with its new IP address.

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 as MHs move 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. 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. 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 [7]. 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. Two proposals [8] and [9] discuss the use of DNS as location manager but lack the performance evaluation and consideration of challenges involved in using DNS as a LM, such as *query failure* and higher traffic load. The *authors are not aware of any (including [7], [8], [9]) previous study* on performance evaluation of DNS as a LM in mobile data networks. The *objective* of this paper is to analyze the performance of DNS as a LM 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) developing an analytical model to study the performance of DNS as LM, and (ii) identifying the impact of subnet radius, MH velocity and network delay on query failure. The result of our analysis shows that within reasonable MH velocity and network latency, DNS can be used as LM with a high success rate.

The rest of the paper is organized as follows. Sec. II describes the deployment of DNS as a LM, 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 [4] is a distributed service that maps host names to corresponding IP addresses. All Internet Service Providers (ISP) maintain Local Name Servers (LNS) that cache recent name to IP mappings. Any subsequent request for the same name is served directly from the LNS. If the LNS does not have an entry for a name, it contacts the root name server that provides the address of the Authoritative Name Server (ANS) for that domain. Under one domain, there might be several sub-domains in a hierarchy, each of which would have an ANS. An ANS can provide addresses of the host of that sub domain. The name to address mapping is finally sent back to LNS where it is cached for a certain period of time (called Time To Live (TTL)) as indicated by the corresponding ANS [4].

In the Internet, location of a host is synonymous to the current IP address of the host. Location management in a mobile data network is challenging as a MH continuously changes its point of attachment and hence its IP address. Basic functionality of a LM encompasses three operations: (i) *Location Update* which consists of updating the LM whenever a MH changes its point of attachment and acquires a new IP address; (ii) *Location Search* is querying the LM to find out the current location of the MH; this takes place before a CN initiates a communication with a MH; (iii) *Location Confirmation* is updating and confirming the location information of the MH at the CN [10].

A. Deployment of DNS as LM

Most of the connection setups generated in the Internet begin with a name lookup via the DNS [11], i.e. domain name is used as the identity of target host. This affirms the notion of considering DNS as a location manager described as follows. Whenever a MH changes its point of attachment, it will register the new IP address with the Authoritative Name Server via dynamic secure update [5]. DNS registers the new IP address for the MH and sends a confirmation message to MH. As DNS is invariant and almost ubiquitous connection originator, all subsequent queries to the DNS for the MH will be served with the new IP address reflecting the new location of the MH.

A LNS caches results of a DNS query for faster resolution of future queries. A cached record has a Time to Live (TTL) entry which is given by the ANS and represents the time after which the LNS should delete the entry; this results in the next query to be resolved by the ANS. In a mobile data network, where the MH frequently changes its point of attachment resulting in frequent updating of the DNS, it is important that all new connections, instead of using cached DNS records at the LNS, query the ANS for the most recent location of the MH. This is required to avoid the CN using cached obsolete IP address of the MH. Caching at the LNS can be avoided by the ANS assigning a TTL value of zero; this will result in all queries to be resolved by the ANS, which has the most updated IP address of the MH.

A significant challenge in deploying DNS as LM is the extra network traffic and load on the server due to the *no-caching* policy resulting in all name lookup queries to come to the ANS. However, with today's hardware advancement, we expect the ANS to be able to handle the extra traffic as the web servers already handle an even higher volume of

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traffic. Another major challenge related to deployment of DNS as a LM arises from the possibility of failure to update the DNS due to loss of DNS update messages. Dynamic Updates in the Domain Name System [12], which allows a device to dynamically update its Name-to-IP mapping at DNS and supports acknowledgement ensuring the safe delivery of the update packet, can be used to solve the problem. The most significant challenge is, as shown in Fig. 2, during the handoff period 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.

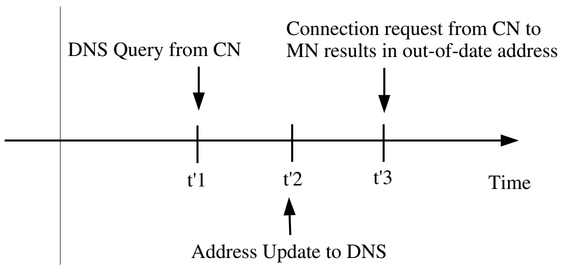

Fig. 2. Effect of obtaining out-of-date address by the CN.

The effect of the above issue is minimized when the handoff process is based on IP Diversity, as in SIGMA, which enables a 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 as described in the following section.

B. DNS as Location Manager for IP Diversity based Mobility Management

We will illustrate the use of DNS as LM for an IP diversity based (e.g. SIGMA [6]) 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. In the overlapping area, ANS responds to location queries with two addresses, the order being determined by the physical location of the MH in the overlapping area.

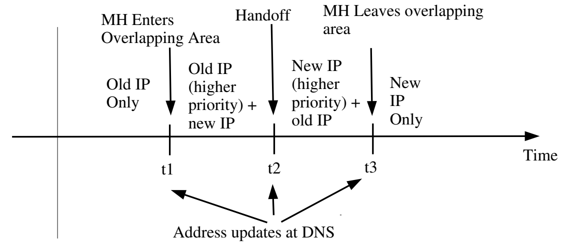

Fig. 3. MH's IP addresses in different stages of Handoff and their respective DNS updates.

III. Analytical Model for Performance Evaluation of DNS as LM

The primary measure of success of DNS as a 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 Sec. III-A, we derive the residence time of a MH in a subnet, in Sec. III-B, we derive the critical time during which location queries carries a possibility of failure, and finally in Sec. III-C we compute success rate based on traffic arrival rate to LM during its residence time and critical time.

A. Calculation of Residence Time

Zonoozi et al. [13] proposes a mobility model that takes into account the disparity of residence time in the call originating cell and the subsequent handoff for cell phone users. We assume that the mobility of cell phone users will represent the mobility of the person who is holding the data communication device, and hence would be able to predict the mobility of the MH. A MH moves to the next location based on its current location and orientation, with a velocity that varies upto V_m.

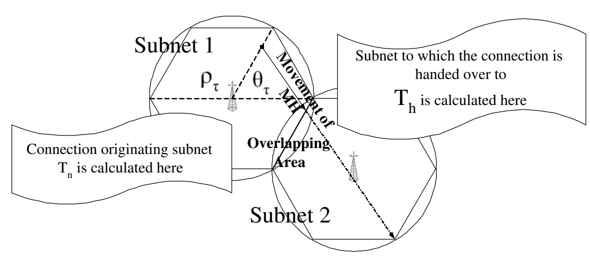

Fig. 4. A graphical representation of the difference between new and handover subnets

Fig. 4 illustrates the difference between the connection originating and handover subnets. This model defines residence time of MH in the connection originating subnet as *new connection subnet residence time*. Similarly, the time spent by MH in a subnet to which the connection was handed over from a previous subnet before is crosses that subnet is defined as *handoff subnet residence time*.

The location of a MH is defined based on its previous instance. Let (ρ_τ, θ_τ) define the location of a MH at any instant τ. Then,

$$\rho_{\tau+1} = \sqrt{\rho_\tau^2 + d^2 + 2\rho_\tau d \cos\gamma_\tau} \tag{1}$$

$$\theta_{\tau+1} = \theta_\tau \pm \alpha_\tau \pm \beta_\tau \pm \beta_{\tau+1} \tag{2}$$

where,

γ_τ Supplementary angle between the current direction of MH and the line connection the previous position of the MH to the AP

α_τ Change in direction with respect to the previous one in time τ

β_τ Magnitude of the angle between MH's previous position to the AP

d Distance traversed between time interval $\Delta\tau$ between τ and τ+1.

If the mobile speed during time interval $\Delta\tau$ is v, then $d = v\Delta\tau$. The signs + or - of Eqn. (2) depend on the successive positioning of the mobile.

For different cases of MH movement corresponding to various orientations and positions, Zonoozi et al. [13] derived two fundamental cases of subnet residence time. Let

T_n New connection subnet residence time

T_h Handoff subnet residence time

V_m Maximum velocity of the MH

R Radius of the subnet

The probability density function of T_n and T_h are then given by $fT_n(t)$ and $fT_h(t)$, where

$$f_{T_n}(t) = \begin{cases} \frac{8R}{3\pi V_m t^2}\left\{1 - \left[1 - \left(\frac{V_m t}{2R}\right)^2\right]^{\frac{3}{2}}\right\}, & 0 \le t \le \frac{2R}{V_m} \\ \frac{8R}{3\pi V_m t^2}, & t \ge \frac{2R}{V_m} \end{cases} \tag{3}$$

$$f_{T_h}(t) = \begin{cases} \frac{4R}{\pi V_m t^2}\left\{1 - \left[1 - \left(\frac{V_m t}{2R}\right)^2\right]^{\frac{1}{2}}\right\}, & 0 \le t \le \frac{2R}{V_m} \\ \frac{4R}{\pi V_m t^2}, & t \ge \frac{2R}{V_m} \end{cases} \tag{4}$$

From Eqns. (3) and (4), we get the mean residence times for new connection and handover subnet residence time as:

$$E[T_h] = \int_0^\infty t.f_{T_n}(t)dt \tag{5}$$

$$E[T_n] = \int_0^\infty t.f_{T_h}(t)dt \tag{6}$$

For an arbitrary speed pdf and zero drift, the mean subnet residence time can be obtained as follows:

$$E[T_n] = \frac{8RE[\frac{1}{V}]}{3\pi} \tag{7}$$

$$E[T_h] = \frac{\pi R}{2E[V]} \tag{8}$$

where E[V] is the mean velocity of the MH.

If there are n handoffs for a particular MH, the total connection time of a MH is given by:

$$T_{cov}^{yes} = E[T_n] + nE[T_h] \tag{9}$$

B. Calculation of Critical Time

For analytical tractability, we make the simplifying assumption that all the queries are processed at the ANS without any referrals (Sec. II). The process of communication initiation between 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 in Fig. 5.

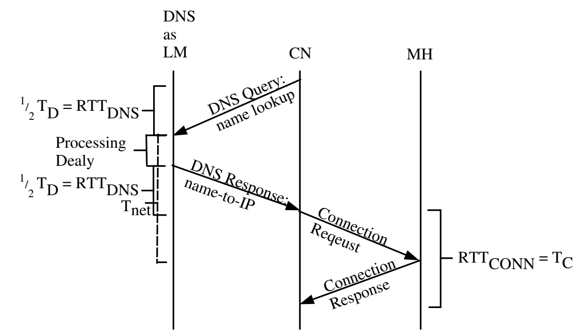

Fig. 5. Timeline of connection initiation from CN to MH.

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

$$T_{net} = \left(\frac{1}{2}\ T_D\right) + \left(\frac{1}{2}\ T_C\right) + T_S^d \tag{10}$$

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 residency 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

$$T_{net} \le (\Delta t_{1+2} + \Delta t_{2+1}) \tag{11}$$

The round trip delay is the sum of the 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

β_{CA} BW of the link between CN and ANS

β_{CM} BW of the link between CN and MH

ψ_D Avg. DNS query packet size

ψ_C Avg. connection request packet size

$\overline{\xi}$ Avg. queuing delay in the network

then, $\frac{1}{2}T_D = T_{CA}^d + \frac{\psi_D}{\beta_{CA}} + \overline{\xi}$ and $\frac{1}{2}T_C = T_{CM}^d + \frac{\psi_C}{\beta_{CM}} + \overline{\xi}$ Therefore,

$$T_{net} = T_{CA}^d + T_{CM}^d + \frac{\psi_D}{\beta_{CA}} + \frac{\psi_C}{\beta_{CM}} + 2\overline{\xi} + T_S^d \tag{12}$$

If the latency in the network increases, T_{net} would increase and violate Eqn. (11). Then, if $T_{net} > (\Delta t_{1+2} + \Delta t_{2+1})$,

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$$T_{cr} = (T_{net} - (\Delta t_{1+2} + \Delta t_{2+1})) \quad (13)$$

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

From Eqn. (10), we get

$$T_{ovr}^{res} = (\Delta t_{1+2} + \Delta t_{2+1}) \quad (14)$$

If d_{sub} is the radius of a subnet, the density function described in Eqns. (4) and (3) gives the probability of residence time of MH in the subnet. For an arbitrary pdf of speed and zero drift, those equations become like Eqns. (8) and (7) and can be evaluated for $R = d_{sub}$ in Eqn. (9).

If d_{ovr} is the overlapping distance, then the residence of the MH in the overlapping area would depend on the velocity and the area. For the ease of calculation, as the overlapping area is very small compared to the area of the subnets, we make the simplistic assumption that in the overlapping area the velocity of the MH is linear hence can be computed as $T_{ovr}^{res} = \frac{d_{ovr}}{E[V]}$. Values retrieved from Eqns. (12), along with this value can be evaluated in Eqn. (13) to get T_{cr}.

C. Calculation of Success Rate

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 out of all the queries. So, if there is n handoffs, success rate, ϕ, can be defined as

$$\phi = \frac{E[\chi(T_{cov}^{res})] - E[\chi(nT_{cr})]}{E[\chi(T_{cov}^{res})]} \quad (15)$$

Values obtained from Eqns. (9) and (13) are used to evaluate Eqn. (15).

IV. Results

Eqn. (15) shows that the success rate of DNS as LM depends on residence time of MH in a subnet and the critical time. Critical time depends on the network latency and the residence of MH in the overlapping region. Network latency, in turn, is dependant on propagation, transmission and queueing delays at the network. Velocity of the MH, radius of the subnet, and overlapping distance gives the time during which it stays in the overlapping region. To summarize, the success rate depends on the network latency, velocity of MH, residence time of MH, and overlapping distance for a given subnet.

One of the measures of performance is the variation of the success rate over different overlapping distances. If the overlapping distance, d_{ovr}, is zero, it would be more like Fig. 2, and as d_{ovr} increases, the possibility of locating the MH even with the old IP address increases. On the other hand, if the latency in the internet and the processing delay at server, T_{net}, are very low, the probability of query failure is also very low. Here, latency represents the sum of propagation, transmission and queueing delays (Eqn. (12)). For a given number of handoffs (n = 10), processing delay at server (T_S^d = 5 sec), network latency (($T_{net} - T_S^d$) = 0.5 sec), and subnet radius (d_{sub} = 750 meter), if the overlapping distance d_{ovr} varies between 0 and 50 meters and if the velocity of MH V varies from 15 meters per second (mps) to 40 mps, we found that for a high MH speed of 40 mps (90 miles per hour), the success rate ϕ remains between 82% and 83%. For slower MH movement, ϕ reaches 95% with an overlapping distance of 50 meters as illustrated in Fig. 6.

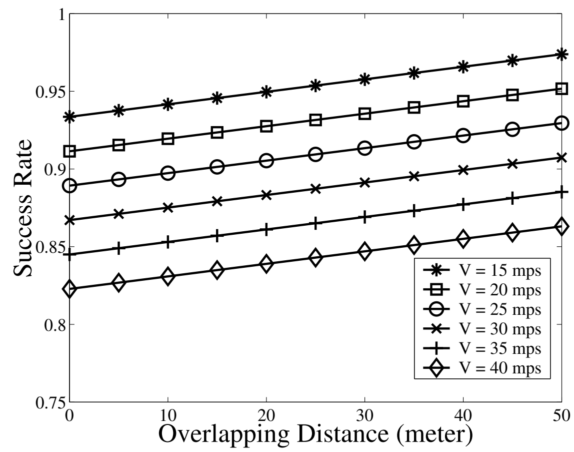

Fig. 6. Success rate against overlapping area for different MH velocity.

For larger subnet radius, the MH will reside in the subnet for a large time with a smaller fraction of time residing in the critical region, thereby reducing the probability of a query failure. If we have a fixed network latency of 0.5 sec with a fixed T_S^d = 5 sec, n = 10 and V = 20 meters per second, and for $0 \le d_{ovr} \le 50$ and $350 \le R \le 750$, we see from Fig. 7 that for $R \ge 650$ meters, ϕ remains above 90%.

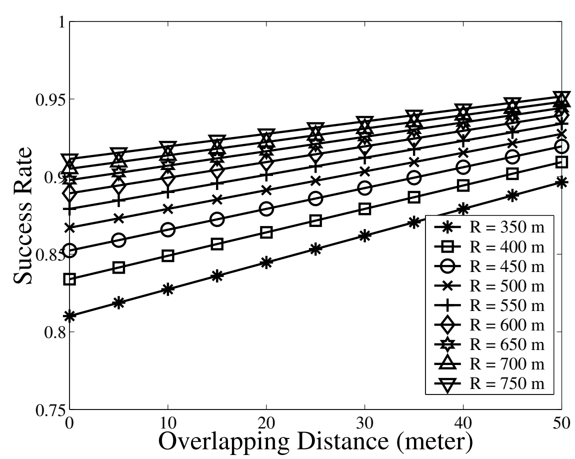

Fig. 7. Success rate against overlapping area for different subnet radius

Another measure of performance is the number of handoffs for a particular connection. The critical regions are created during the handoff process, hence fewer number of handoff

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would generate fewer failures. For a network latency of 0.5 seconds, T_S^d = 5 sec, V = 20 mps, R = 750 meters, and for $0 \leq d_{ovr} \leq 50$ and $0 \leq n \leq 10$, the ϕ is higher for lesser number of handoffs. Accordingly, we see from the graph that for n = 0, ϕ = 1. For the given configuration, $\phi \geq 90\%$ for all n. Fig. 8 shows how success rate changes over overlapping distance with varying n.

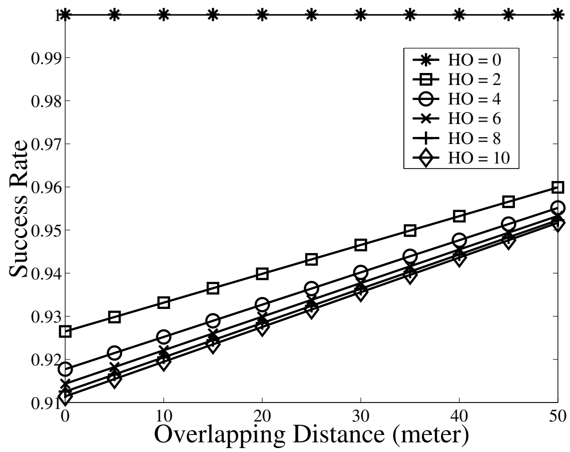

Fig. 8. Success rate against overlapping area for different number of handoffs.

Now, depending on the encryption algorithm and security measures, possible hierarchical deployment of DNS system or for shared system, query processing at ANS might be high. So, for a given $(T_{net} - T_S^d)$ = 0.5 seconds in the network, if we have $0 \leq d_{ovr} \leq 50$, and d_{sub} remains at 750 meters with fixed V = 20 mps and n = 10, we found out that for a high delay of 6 seconds, we get $\phi \geq 90\%$. Even though the graph shows the upto a very high latency, usually the DNS request query processing time is rather small. Fig. 9 depicts the effect of T_S^d on varying overlapping area.

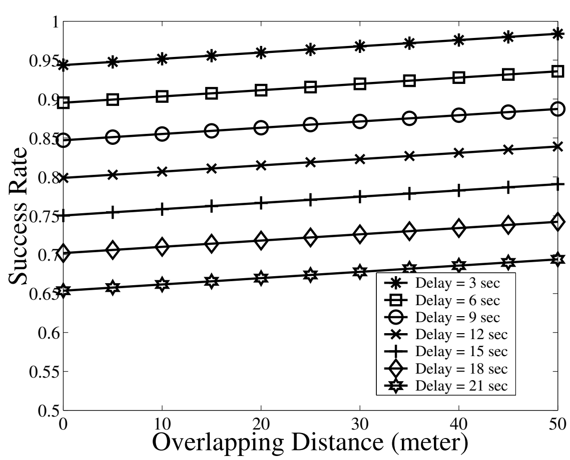

Fig. 9. Success rate against overlapping area for different query processing time at server.

Thus, we can conclude that within reasonable latency and overlapping region, DNS would be able to successfully serve as a location manger.

V. CONCLUSIONS

DNS is already an established technology implemented in the Internet and is the originator in most of the connections. In this paper, we have considered DNS as a Location Manager for finding a mobile host in a wireless mobile network. Previous studies did not analyze the performance of DNS as a location manager in mobile data networks. In this paper, we have developed an analytical model to study the performance of DNS as a location manager in terms of success rate, internet traffic load, velocity of MH and subnet radius. Our results clearly show that DNS is a feasible solution for location management even under some tough network and mobility scenarios.

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