AN ANALYTICAL PERFORMANCE EVALUATION OF LNS/SMP MOBILITY MANAGEMENT SCHEME

Raquel Morera, Stefano Galli, Anthony McAuley
Telcordia Technologies, Inc.
Piscataway, NJ

ABSTRACT[1]

Future military networks must be self-configured and self-maintained so that they can be rapidly deployed and quickly reorganized when needed. Moreover, unlike commercial networks, all elements can be highly mobile, including the routers and servers that make up the communications infrastructure. In order to address this need for new mobility management solutions, we proposed a mobility management mechanism based on Logical Name System (LNS) to support location management and a Session Maintenance Protocol (SMP) to maintain ongoing sessions. This paper compares the performance of the proposed LNS/SMP approach with standard Mobile IPv4 (MIPv4) on the basis of an analytical framework. Our analysis identifies network and traffic conditions under which one approach outperforms the other.

INTRODUCTION

With the growth in the number of portable and mobile terminals and the need of seamless roaming among different wireless technologies, mobility management is increasingly needed in both commercial and military environments. Future military networks must be self-configured and self-maintained so that they can be rapidly deployed and quickly reorganized when needed. Unlike commercial networks, all elements can be highly mobile, including the routers and servers that make up the communications infrastructure. Network services such as location management must be maintained even when the network is split into isolated islands. Therefore, when a path exists, nodes, users and services must be found rapidly and connections maintained, so that the information can reach the right place at the right time.

In order to address this need for new mobility management solutions, we previously proposed in [1], [2]: a) a mobility management mechanism based on LNS (Logical Name System) to support location management and; b) an SMP (Session Maintenance Protocol) to maintain ongoing sessions. In the sequel, we refer to it as the LNS/SMP mobility management solution. Just as with DNS or SIP, a hierarchy of LNS servers provides dynamic name-to-address mappings; but, unlike these approaches, the service is robust to network splits and name to address resolution is done very close to the destination’s location. Each LNS server handles all the mobility management for a mobile node (MN) within its own domain, i.e. the MNs only performs local registrations. The local LNS is referred as topological LNS (T-LNS). The registration is sent outside the local LNS domain only when the MN moves to a different LNS domain, similarly to hierarchical MIPv6. The logical LNS (L-LNS) registers in what T-LNS the node is local to. For packet delivery, SMP may use direct binding with the corresponding nodes (CNs) as in MIPv6 with route optimization. In addition to route optimization, this mechanism avoids congestion on the Home Agent (HA) links and allows communication even if the home server is not available.

This paper compares the performance of the proposed LNS/SMP approach to standard Mobile IPv4 (MIPv4) on the basis of the analytical framework presented in [3], [4], [7]. Our analysis, identifies network and traffic conditions under which one approach outperforms the other. This paper: a) extends the type of mobility protocols addressed in [3]-[4] to cover protocols that allow local registration, like LNS/SMP; b) derives new equations for registration and packet delivery cost in LNS/SMP; c) investigates the effect that the number of subnets covered by a local LNS has on protocol performance.

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COST OF MOBILITY MANAGEMENT MECHANISMS

The analytical framework for the comparison of mobility protocols developed in [3][4] is based on the original paper by Wang, Chen and Ho [5], where the authors propose modeling mobile IP networks by exploiting modeling techniques available from studies on Location Management for Personal Communications and assigning costs to specific operations performed by nodes. Xie and Akyildiz [6] use the model in [5] to calculate the total signaling cost and packet delivery cost for a dynamic regional location management scheme.

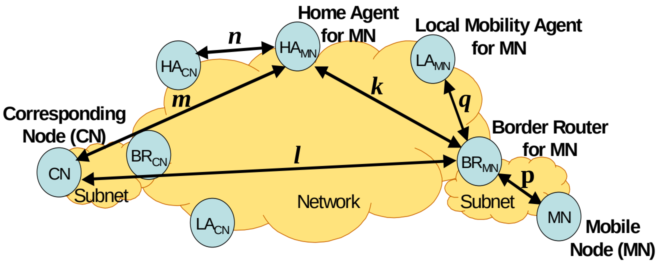
Figure 1 shows the main elements involved in a generic mobility management protocol. For a specific protocol, some elements are named differently than those shown in Figure 1. In Mobile IPv4 (MIPv4), for example, the Border Node represents the Foreign Agent (FA). In the LNS/SMP approach, the Local Mobility Agent (LA) represents the topological LNS (T-LNS). In the figure, distances between mobile entities are measured in number of hops (IP or lower layer (MAC)). For the sake of simplicity and without loss of generality, in the sequel we will assume $p=1$.

Mobility management protocols use a combination of simple basic mechanisms to locate and provide continuous connectivity between nodes. The basic mechanisms with an associated cost are: 1) upon moving to a new subnet, **Registration** of the newly acquired (care of) IP Address with the location server and possibly other entities in the network; 2) **Packet data delivery** between CN and MN 3) **Handoff delay** when a MN changes its IP address.

The above mechanisms have an associated cost which we assume is a function of: a) **Processing cost** C_p of registration and data messages at mobility agents or nodes; b) **Transmission cost** C_t for sending registration and data messages. We assume the per packet, per agent/node processing cost is proportional to a constant C_p. Although this cost may depend on many factors (e.g., type of node, scheduling scheme, number of packets to be processed at every node, etc.), we will assume for the sake of simplicity that processing costs are the same in any mobility agent. We also assume that the per packet, per hop transmission cost is proportional to a constant C_t. C_t includes all the per packet processing at every hop, including, for example, queuing, forwarding (lookup) and transmission. We here assume that all hops have similar transmission costs. Thus, for example, transmission between mobile entities at a distance k costs kC_t.

As a first order approximation, in lightly loaded networks and stable links, the constants C_t and C_p will not change over time. In more heavily loaded networks, the values of C_t and C_p may vary in time and be a function of the network traffic and load at a specific node or agent.

In the next sub-sections, we will find equations that quantify the registration cost, packet delivery cost and overall mobility cost for the two protocols under comparison, MIPv4 with FA and LNS/SMP approach. The case of the handoff delay can be found in [3] and [7].



k	Number of hops on shortest path between BR and HA
l	Number of hops on shortest path between BR and CN
m	Number of hops on shortest path between HA and CN
n	Number of hops on shortest path between HA$_{MN}$ and HA$_{CN}$
p	Number of hops on shortest path between BR and MN
q	Number of hops on shortest path between BR and LA
s	Number of sessions between MN and all its CNs
w	Number of LA registrations for each HA registration
C_p	Cost to process packet/message at a node.
C_t	Cost to transmit one message over one hop

Figure 1: Relative Positions of Nodes and Agents.

Registration Cost (REG)

In MIPv4, the MN sends the registration message via the FA that is topologically close to the MN. This registration mechanisms is called *indirect home registration* in [3]. The FA must process the registration and forward it to the HA$_{MN}$. The HA$_{MN}$ must process the registration message, update the HA$_{MN}$ table with the new IP address, modify the tunnels and send an acknowledgment to the MN via the FA. If the MN moves back to its HA$_{MN}$'s subnet, then the MN can send a registration packet directly to the HA$_{MN}$ which processes the packet, modifies the tunnel end points (if any) and returns the acknowledgment directly to the MN. Thus, the cost of *indirect* home registration after the MN has moved to a new cell served by a new FA which is at a distance k from the HA$_{MN}$ is:

$$REG_{ih}(k) = \begin{cases} 2C_p + 2(k+1)C_t & \text{, MN roaming} \\ C_p + 2C_t & \text{, MN at home } (k=0) \end{cases} \qquad (1)$$

In LNS/SMP approach, there are two kinds of registration: *local* (with topological LNS (T-LNS)) and *home* (with home LNS (H-LNS)). A MN performs a local registration when moves to a different subnet (i.e. changes IP address) but remains under the service area of the same T-LNS prior to the change. When a MN moves to a subnet served by a different T-LNS, it registers its name and IP address with the serving T-LNS. The new T-LNS, sends a registration message to the mobile’s home LNS that contains the mobiles name and the serving T-LNS IP address. Since packet exchange for a *home* registration in SMP is the same as for MIP with FAs (the T-LNS and the H-LNS act as the FA and HA, respectively), we have:

$$REG_{smp}^{(Home)}(k)=\begin{cases}2C_p+2(k+1)C_t & \text{, MN roaming}\\ C_p+2C_t & \text{, MN at home}\,(k=0)\end{cases} \tag{2}$$

where k is the distance between the T-LNS and H-LNS.

Assuming the T-LNS is h (average) hops away from the MN, the cost for a local registration is given by:

$$REG_{smp}^{(Local)}=C_p+2(h+1)C_t \tag{3}$$

In general, it is not possible to know a priori whether the MN is going to perform a local or home registration, since this depends on the node’s mobility pattern and the particular network topology. Thus, for the purpose of our analysis, we will assume that in average, the MN performs a *home* registration every w consecutive *local* registrations. Thus, the average registration cost (REG$_{\text{smp}}$) is as follows:

$$REG_{smp}(k;w)=\begin{cases}\dfrac{(2+w)C_p+2(k+w+1)C_t}{w+1}, & k\neq 0\\[2ex] C_p+2C_t, & k=0\end{cases} \tag{4}$$

As the local registration packet might need several hops to reach the T-LNS, the results found in this section may be considered valid only under the assumption that the coverage area of an T-LNS is small or under the assumption that w is small. The more general case, where the size of the coverage area of the LS is taken into account, is currently under investigation by the Authors.

In LNS/SMP, the MN sends a binding update (BUD) to the CN upon an IP address change. If the MN is mainly the receiver of the transmission, a BUD is sent to the CN (explicit BUD). On receiving the BUD message the CNs process the message, and may reply back to the MN acknowledging successful registration. In SMP, every packet carries a Session ID (SID) that remains unchanged for the duration of the session, independently of the node mobility. When the CN receives a packet with a new IP for a given SID, it performs a binding update for that SID. Then, if the MN is the transmitter, there is no need to send an extra packet.

If we assume that the CN is at a distance l from the MN, the cost for sending an explicit BUD to a single CN is:

$$BUD_{cn}(l)=C_p+2(l+1)C_t \tag{5}$$

Therefore, the total REG in SMP when the CN is the receiver of the communication is:

$$TotREG_{smp}(k,w,S_r,l)=REG_{smp}(k,w)+S_r\,BUD_{cn}(l) \tag{6}$$

where S_r is the number of CNs with whom the MN is engaged in a session.

Packet Delivery Cost (PDC)

MIPv4 with FA mode and SMP use different mechanisms for packet delivery. The former uses triangular routing while the latter uses direct packet delivery.

In triangular routing, a CN sends packets to the MN’s home address regardless of the location of the node. The HA$_{\text{MN}}$ intercepts and tunnels the packets to the FA at the edge of the IP subnet where the MN is registered. The FA de-tunnels these packets and forwards the data packets to the MN. In the reverse direction, the MN sends packets directly to CN home address.

The cost of sending a packet to a MN via triangular routing is the cost of transmitting: a) the data packet a distance m (between CN and HA$_{\text{MN}}$), b) the tunneled data packet a distance k (between HA$_{\text{MN}}$ and BR), and c) the data packet a distance p (between the BR and MN). Let $C_{t,dat}$ be the per hop transmission cost of a data packet and be $C_{t,tun}$ be the transmission cost of the tunneled data packet. As costs are a function of the packet size, the transmission cost of a tunneled packet is higher than that of a plain packet; however, for large packet sizes, both can be considered the same: $C_{t,dat}=C_{t,tun}=C_t$. The cost of sending a packet to a MN via triangular routing is:

$$PDC_{tri}(k,m)=2C_p+(m+k+1)C_t \tag{7}$$

Triangular routing requires: a) the HA to be 100% operational for the duration of the packet transmission, b) the path between the CN and HA, HA and FA and FA to CN be available. All packets destined to nodes of the same home network follow the same path. Thus, when this path cannot be guaranteed to be stable a large number of communications can be affected.

SMP protocol is targeted to dynamic ad hoc networks where links are highly unstable and nodes are highly mobile. Thus, packet delivery does not rely on the HA$_{\text{MN.}}$ SMP sends packets directly on the shortest path between CN and MN, as there is no concept of home IP address in this approach. Thus, the cost of sending a packet to a MN is expressed only in terms of the distance l between the two nodes:

$$PDC_{cn}(l)=(l+1)C_t \tag{8}$$

Packets sent by a MN to its CN follow the same path in both protocols. MIPv4 uses the home IP address to send the packet. SMP send the packets to the CN with the newly acquired IP address and the CN updates the binding from SID to IP address. The cost of sending a packet by a MN is the same in both protocols, that for space constrains we do not derive here.

AVERAGE REG AND PDC: COMPARATIVE ANALYSIS BETWEEN MIPV4 AND SMP

In this section we carry out a comparative analysis between MIPv4 and SMP. As it is difficult to assign absolute values to the basic costs C_t and C_p and we are only interested in a comparative analysis and not in the cost of a mechanism per se, we analyze the ratio of the costs obtained in the previous section. If the ratio of some metric is higher (lower) than one, then MIPv4 performs worse (better) than SMP with respect to that particular metric. At the crossover point (ratio equal to one), MIPv4 and SMP perform the same. By analyzing the ratio of the metrics, the problem of assigning specific values to each basic cost is by-passed.

Averaging Metrics over d movements

REG, PDC, and BUD are highly dependent on the distances between mobile entities. As the MN moves, these costs will therefore change. To provide more realistic results, it is better to express the cost metrics found averaged over *d* consecutive random movements. For the sake of brevity, in this paper we do not derive the equations for averaging over *d* random movements which can be found in [3], [4], and [7]. We here summarize, however, the assumptions taken into consideration when deriving such equations.

Following [5], we model the network as a grid of equal-sized, non-overlapping, rectangular cells. Each cell represents an IP subnet. Note that the abstract representation of IP subnets does not necessary need to match a geographical area. The distance between any two cells in the grid configuration is measured by the minimum number of cell boundary crossings, i.e. IP hops, that is required to travel from one cell to the other. If we assume a random walk mobility model, the MN may travel to one of the four neighboring cells with equal probability ¼. For simplicity, we consider the case where the MN is the only mobile entity, whereas CN, HA_{MN}, FA do not move; thus *m* can be considered fixed (see Figure 1). While *l* and *k* change as the MN moves, they cannot take arbitrary value; rather they are limited by:

$$m_{\min} = |k - l| \le m \le k + l = m_{\max} \quad (9)$$

Average REG Ratio

In this Section, we will analyze the behavior of the ratio between the registration cost of MIPv4 ($\overline{REG}_{mipv4}^{(d)}(k)$) averaged over *d* random movements, and the corresponding cost of SMP ($\overline{REG}_{smp}^{(d)}(k,w)$). For MIPv4, *k* represents the initial distance between the HA and the serving FA before the MN starts the *d* movements, whereas for LNS/SMP *k* denotes the initial distance between the T-LNS and the H-LNS before the MN starts the *d* movements. The parameter *w* expresses the average number of local registrations that the MN performs per every home registration; if *w*=0, all registrations in SMP are home registrations as in MIPv4.

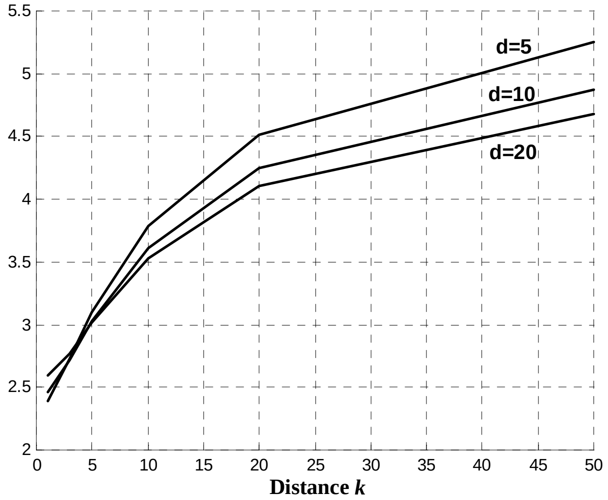


Figure 2: Average REG ratio (*w*=5)

The average REG ratio is plotted for *w*=5 in Figure 2, as a function of *k* and for several values of *d*. It can be seen that the benefit of carrying *w* local registrations per home registration translates into a better performance of SMP in comparison to MIPv4 for any value of *k* (ratio is always larger than one). From Figure 2 it also appears that the ratio increases unboundedly with *k*. However, it can be proven analytically that the ratio is upper bounded as *k* grows. In fact, it is possible to show ([7]) that, for small values of *w*, the REG ratio boils down to:

$$RatioREG(w,k) \equiv \frac{\overline{REG}_{mipv4}^{(d)}(k)}{\overline{REG}_{smp}^{(d)}(k,w)} \cong \frac{2(w+1)(k+1)+3(w+1)}{2(k+1)+3(w+1)} \quad (13)$$

Now, passing to the limit for *k*→∞, we obtain:

$$RatioREG^{\infty}(w) = \lim_{k \to \infty} RatioREG(w,k) = w+1 \quad (14)$$

The result in (14) is confirmed by Figure 2, where the curves reach the asymptotic values of *w*+1=6 as *k* increases. Therefore, we can conclude that for small values of *w*, the asymptotic average reduction offered by SMP with respect to MIPv4 in the signaling due to registration overhead is linearly proportional to *w*.

Average PDC

In this section, we will analyze the behavior of the average PDC ratio. Although, it is common engineering knowledge that triangular routing is less efficient than direct communication between nodes, it has never been proven how much gain route optimization offers with respect to triangular routing. Under the assumption that $k,l>>d$ (the MN moves within an area much smaller than the distances between MN and HA and MN and CN), it is possible to show that the average PDC ratio boils down to the following expression:

$$\frac{\overline{PDC}_{tri}^{(d)}(k;m)}{\overline{PDC}_{cn}^{(d)}(l)} \approx \frac{k}{l+1} + \frac{2C_p}{(l+1)C_t} + \frac{m+1}{(d+1)(l+1)} \qquad (15)$$

Let us first analyze this ratio under the assumption that, processing cost at mobility agents dominates with respect to transmission cost ($C_p>>C_t$). In this case, the ratio (15) is larger than unity thus indicating that triangular routing is less efficient than route optimization. Moreover, the higher the processing costs, the higher this gain is.

If transmission costs dominate, eq. (15) becomes:

$$\left.\frac{\overline{PDC}_{tri}^{(d)}(k;m)}{\overline{PDC}_{cn}^{(d)}(l)}\right|_{C_t>>C_p} \approx \frac{k}{l+1} + \frac{m+1}{(d+1)(l+1)} \qquad (16)$$

Equation (16) is valid under the assumption that *k* and *l* are much larger than *d*. Since it is difficult to infer meaningful results from (16), let us consider first the case $k=l$, i.e. the case where the distance *l* of the CN from the receiving MN is equal to the distance between the HA and the FA serving the receiving MN, and then consider the limit where *k* goes to infinity (since $k=l$, recall that $0\le m\le 2k$ – see (9)):

$$\lim_{k\to\infty}\left.\frac{\overline{PDC}_{tri}^{(d)}(k;m)}{\overline{PDC}_{cn}^{(d)}(l=k)}\right|_{C_t>>C_p} \approx \begin{cases} 1, & m=0 \\ 1+\dfrac{2}{d+1}, & m=2k \end{cases} \qquad (17)$$

Equation (17) shows that, in the most unfavorable case for MIPv4 when $k=l$ ($m=2k$), the gain of SMP over MIPv4 is limited to three in a static situation ($d=0$) and it decreases as the MN makes more and more movements. Note that we arrive at the same result in (17) even in the case when neither cost dominates [7].

Let us now look at the behavior of the PDC ratio for the more general case of $k\neq l$. This is plotted in Figure 3 for $d=1$ and for $m=m_{max}=k+l$, versus the ratio k/l and for different values of *l*. As the plot confirms, even for the more general case of $k\neq l$ the PDC in MIPv4 is always higher than in SMP. In particular, the cost ratio gain in SMP is very high since the CN is very close to the MN and very far form the HA of the MN ($k>>l$, $k/l\to\infty$, see right half of Figure 3). As the distance of the CN form the MN grows with respect to the distance between the MN and its HA ($k<<l$, $k/l\to 0$, see left half of Figure 3) the cost ratio decreases towards one. A similar behavior also occurs for other values of *m* and *d*.

On the basis of the previous considerations, we can then state that the PDC of SMP is always better (or at the least the same) than the PDC of MIPv4.

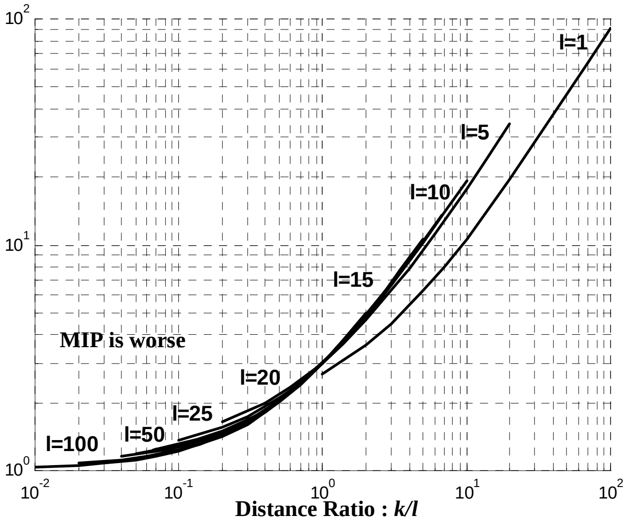


Figure 3: Average PDC ratio (m=k+l)

AVERAGE OVERALL MOBILITY COST

The REG, PDC, and BUD costs focus on the different elements of a mobility protocol, but do not provide the cost of a mobility protocol as a whole. For example, when considering the disadvantage of triangular routing versus route optimized schemes, we cannot neglect the disadvantage of sending BUDs to all the CNs transmitting to the MN when the MN is mainly the receiver in order to maintain session continuity. For this reasons, a new metric has to be introduced. We here define a novel metric, the Overall Mobility Cost (OMC). OMC captures the overall performance of a mobility protocol. We conjecture that such a global metric should encompass: a) registration cost; b) packet delivery cost; c) mobility rate λ_m (average number of registrations made by mobile in the unit time); packet arrival rate λ_p, average number of packets generated in a session in the unit time; number of active sessions S_r in which the moving MN is a receiver.

On the basis of these considerations, we define the OMC as in the following:

$$\overline{OMC}^{(d)} = \lambda_m \overline{REG}^{(d)} + S_r \lambda_p \overline{PDC}^{(d)} \tag{18}$$

The OMC is expressed in terms of cost per unit time.

For the case of MIPv4, the OMC per unit time $\overline{OMC}^{(d)}_{mipv4}(k;m)$ is defined as in the following:

$$\overline{OMC}^{(d)}_{mipv4}(k;m) = \lambda_m \overline{REG}^{(d)}_{ih}(k) + S_r \lambda_p \overline{PDC}^{(d)}_{tri}(k;m) \tag{19}$$

For the SMP case, the OMC per unit time $\overline{OMC}^{(d)}_{smp}(k;l)$ depends on the REG and on the PDC as in MIPv4, but also on the BUD. Therefore, we can define the OMC for the case of LNS/SMP (when considering the MN as a receiver) as follows:

$$\overline{OMC}^{(d)}_{smp}(k;l) = \lambda_m \overline{TotREG}^{(d)}_{smp}(k,w,S_r,l) + S_r \lambda_p \overline{PDC}^{(d)}_{cn}(l) \tag{20}$$

Note that here k represents the *initial*, i.e. prior to the MN d movements, distance between the serving FA (T-LNS) and the HA (H-LNS), whereas l indicates the initial distance between the MN and the CN.

Comparative Analysis

We assume that the processing costs and the transmission costs have comparable weight. The two cases where either the processing cost or the transmission cost are vanishing are addressed in [7]. The OMC ratio is then:

$$\begin{aligned} & RatioOMC(k;l;m;w;d;\lambda_m;S_r;\lambda_p) = \\ & = \frac{\overline{OMC}^{(d)}_{mipv4}(k;m)}{\overline{OMC}^{(d)}_{smp}(k;l)} = \\ & = \frac{\lambda_m \overline{REG}^{(d)}_{ih}(k) + S_r \lambda_p \overline{PDC}^{(d)}_{tri}(k;m)}{\lambda_m \left[\overline{REG}^{(d)}_{smp}(k,w) + S_r \overline{BUD}^{(d)}_{cn}(l) \right] + S_r \lambda_p \overline{PDC}^{(d)}_{cn}(l)} \end{aligned} \tag{21}$$

Figure 4 shows the plot of (21) for $\lambda_p = \lambda_m = S_r = 1$, $m = m_{med} = (k + l + |k - l|)/2$ (corresponding to the intermediate case between m_{min} and m_{max}; see eq. (9)), $w=0$ (no local registrations allowed), and for the two cases of $d=0$ and $d=20$. The reference plane at unitary height is also plotted to better show where MIPv4 is worse than LNS/SMP (surface above the unitary plane) and vice versa (surface below the unitary plane). It is clear from these two figures that there are situations where MIPv4 is better than LNS/SMP and vice versa. The OMC ratio ranges between 0.5 and 2 for any combination of the distances k and l. However, if local registrations are allowed in LNS/SMP, the advantage of LNS/SMP over MIPv4 becomes substantial as shown in Figure 5.

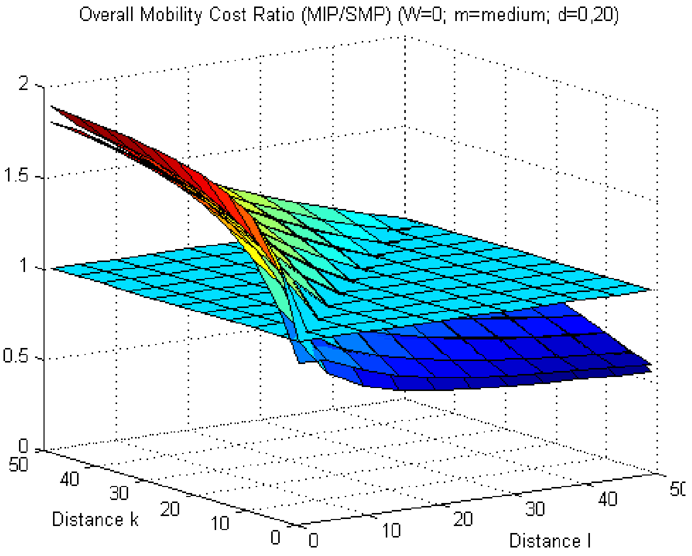


Figure 4: OMC for m_{med}, $w=0$, and $d=0$, 20.

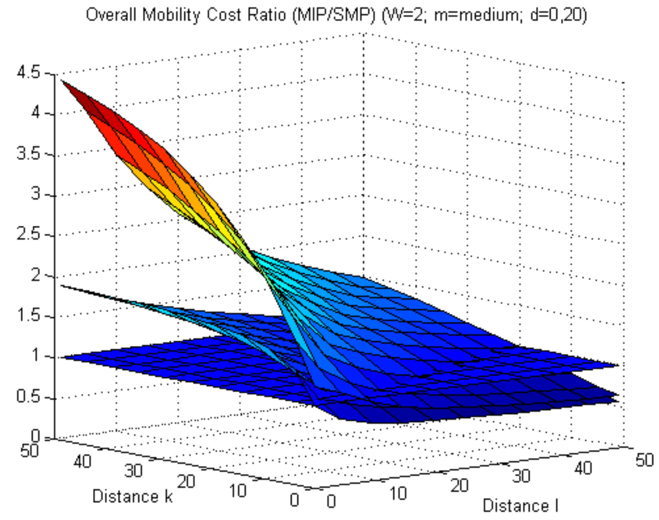


Figure 5: Same as in Figure 4, but with $w=2$.

It is also interesting to look at the behavior of the OMC ratio for fixed values of k and l and as a function of the mobility rate λ_m and of the number of ongoing sessions S_r. Note that the case of varying packet arrival rate per session in the unit time is less interesting. In fact, when λ_p increases and S_r is fixed, the OMC ratio converges to the PDC ratio which is always greater or equal to one (triangular routing is *always* worse than direct packet exchange, see considerations made in previous Section).

Figure 6 is obtained for fixed $S_r \cdot L_p$, i.e. maintaining constant the total number of packets $S_r \cdot \lambda_p$ received by the MN from all its CN in the unit time, and it shows the OMC ratio for $k=10$, $l=5$, and for $S_r \cdot \lambda_p = 1$, 10, 100. As expected, when the total number of packets received by the MN increases the OMC ratio increases, i.e. becomes more favorable for LNS/SMP. However, it can also be seen that the OMC ratio decreases if either the number of sessions or the mobility rate grows. On the other hand, the dependence of the OMC ratio on the mobility rate λ_m is very small for small S_r, and becomes larger when the number of sessions grows. From Figure 6 we can also see that, when k and l have similar values, then the gain of SMP over MIPv4 is limited to a factor of around 2 when S_r and λ_m are small. However, when S_r and λ_m grow, MIPv4 can be as much as 5 to 10 times better than SMP.

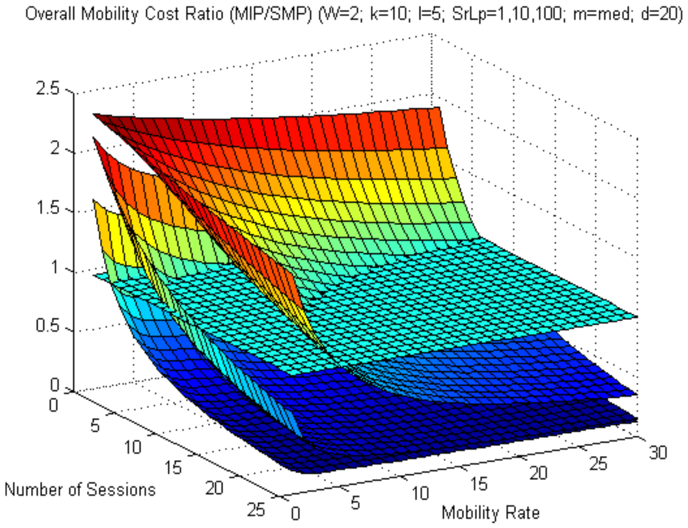


Figure 6: OMC ratio for k=10, l=5, Sr·   p =1,10,100

CONCLUSIONS(2)

This paper extends the general framework for the analytical analysis of mobility protocols proposed in [3], [4], [7] (where MIPv4 with MIPv6 are compared) and analyzes the behavior of the LNS/SMP protocol proposed in [1]-[2] Thus, it represents a step in the direction of solving an important problem: the lack of formal methods for the objective comparison of schemes.

LNS/SMP and MIPv4 protocols use different mechanisms for node location and packet delivery. Registration cost with the mobility servers is always lower in LNS/SMP than MIPv4 as LNS/SMP uses local and home registrations and MIPv4 only uses home registrations. LNS/SMP performs a delayed name to IP address binding at the T-LNS, making it more suitable for highly dynamic networks. LNS/SMP does not require a mobility server like the HA in MIPv4 for packet delivery. Then, it is more suited for networks where HA can be mobile and links are highly unstable, such as MANETS. Besides confirming the intuitive (e.g. route optimization is less costly than triangular routing for packet delivery), our analysis shows quantitatively the benefits of the different mechanisms for a wide range of parameters.

We have also studied the asymptotic behavior of the comparative analysis. Results shed good insight into which protocol is preferred in a particular situation. The analysis shows that neither MIPv4 nor LNS/SMP have a clear and general advantage over the other. Similar results can be drawn when comparing MIPv4 and MIPv6 [3], [4], [7]. In our opinion, highly mobile networks as the future military ones will need to have the capability to switch between different protocols on a case-by-case basis so that they can make best use of the inherent strengths of every protocol without having to cope with the weaknesses.

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