An allocation strategy for Mobile Agent in a Multi Retailer Network supporting Personal Communication Services

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Abstract. *This paper presents a strategy for the support of Personal Communication Services in TINA compliant systems through the use of mobile agents. The paper reflects the vision of the EC/ACTS research project DOLMEN that has developed OSAM, an Open Service Architecture for fixed and Mobile environments.* A*fter introducing the principle of retailer federation in a multi-domain environment, the paper analyses how federation can be established to support migration of agents acting on behalf of the user within the network. Moreover, a strategy for mobile agents allocation is presented and its effectiveness is evaluated according to two different performance metrics: the signalling load on the network and the average response time for service requests.*

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1. Introduction

The need for injecting terminal and personal mobility features into conventional service architectures is today rising in the domain of integrated fixed and mobile networks to support the expected Personal Communication Services (PCS). Future mobile computing systems, in fact, will provide users with a consistent working environment where they will be able to access their usual files, e-mails and services by using any fixed or mobile terminal placed anywhere. Such systems will increase their popularity by guaranteeing universal access to Internet resources in a seamless way for the user, who will get the feeling to work on his terminal in his office while he is travelling around the world.

In this perspective the definition of a Service Architecture enhanced with mobility support, represents a key passage and work is today in progress to develop middleware tools for the explicit support of nomadicity and mobility. At the present time commercial products, like CORBA and DCE platforms, are powerful instruments currently used in object-oriented distributed computing environment, but they should be enhanced with value-added building blocks that support mobile applications. In this perspective a big effort is being made within the TINA (Telecommunication Information Networking Architecture) consortium [i] which is leading to an emerging de facto standard as a service architectural framework.

In order to deploy mobile computing in a wide environment where personal and terminal mobility are supported, a number of problems must be solved, paying special attention to the provision of multimedia services. In particular, it must be considered that wireless connections are often prone to sudden failure, that they perform poorly and that the processing capability of mobile computers is frequently limited with respect to the requirements of multimedia services. A possible answer to mobility requirements is the introduction of mobile agents. These agents, acting on behalf of the user within the network, will offer performance-effective features like, for example, continuing their interactions with the system resources even if the wireless connection goes down, reducing signalling on both the wireless and wired connections, reducing processing on mobile terminals, and guaranteeing the user with a seamless access to the system. In addition, migrating the agents closed the user location allows users to get faster responses to their queries.

Nevertheless, it should be stressed that agent migration causes some problems when it has to be applied in a wide environment where a number of service providers and network operators exist.

In this paper, we introduce some of the results achieved by the DOLMEN project on the problem of agent migration between different provider domains in a mobile computing environment. In particular, stemming from the TINA reference model, in Section 2 we introduce the multi-retailer concept in the PCS environment, and after presenting the principle of retailer federation, in Section 3 we analyses how this federation can be established to support mobile agents acting on behalf of the user within the network. Section 4 presents the impact of the multi-retailer concept on the TINA enhanced computational model. In the paper then we focus on the performance evaluation of the proposed solution and on the definition of a strategy for the allocation of mobile agents in the network. In particular in Section 5 we show how to compute a signalling load analysis in order to evaluate the effectiveness of agent migration and in Section 6 we show how to define a criteria for agent migration according to QoS perceived by the users in term of the average response time for service requests. Section 7 provides conclusions.

2. The Multi-retailer concept in the TINA Service Architecture

The TINA Service Architecture [ii] has defined a set of concepts, principles, rules and guidelines for creating and operating telecommunication, management and information services. The elements in a TINA environment are modelled by distinct components, with prescriptive functionality and interactions. The TINA Service Architecture follows an ODP like approach, thus dealing with aspects related to the enterprise, business, information, as well as computational viewpoint.

In addition to the TINA Service Architecture, the TINA Consortium has defined the TINA Business Model [iii].

Scope of the TINA Business Model is to define the interaction between business administrative domains in terms of contracts, business roles, business administrative domains and reference points in order to ease the application of TINA in a multi-provider, multi-vendor environment.

In particular, in an extensive PCS environment where mobile computing is supported, several providers are

active. To ensure that such large systems can evolve to TINA compliant systems, the concept of multi-provider environment is to be introduced, meaning that mobility is considered in terms of federating providers.
The concept of federation applies to all the business roles defined in the TINA Business Model, but its effectiveness is to be evaluated depending on the specific functionality they provide. In particular, whereas federation between business roles providing connectivity (*connectivity provider*) is always necessary in order to support the roaming user in any remote domain, the federation between those business roles which provide services to the users, and which has in charge of maintaining the user profile of subscription (*retailer*), is yet an occurrence to be evaluated.
In fact, in the context of mobility where the end-user is allowed to roam all over the world and to use his subscribed and personalised services at any place and at any time, situations similar to the "Sushi" example can occur. A business man from Europe, on a trip in Japan, wants to call the sushi delivery service located next door. In terms of the service architecture, the request for the Sushi service is a two-party call with corresponding service session and communication session. The following question arises:

Which retailer domain will accommodate the service session: the retailer domain in Europe where the caller has the subscription or the retailer domain in Japan close to the caller's location?

The new element which this question implicitly introduces, with respect to the TINA principles, is that, whilst in TINA the retailer is always assumed to maintain the control of data concerning the user subscription, here we envisage the possibility to delegate this control to another retailer. In fact, the answer to the above question should be to locate the service session in a retailer domain close to the user because of the following service provisioning aspects:

- *Performance*: The transfer of service invocations and their responses over long distances may require a considerable amount of time which decreases service performance.
- *Resources*: Long paths between the point at which the system is accessed and the place where service invocations are processed require a significant amount of resources.
- *Costs*: Long paths between the point at which the system is accessed and the place where service invocations are processed increase service provision costs.
- *Data Integrity*: Information transferred over long distances has a higher probability of being corrupted which necessitates additional protection.

In order to control the service session in a retailer domain close to the user, a retailer federation is required and the notions of *Visited Retailer Domain* and *Home Retailer Domain*, as defined in [vi], is introduced in this paper.
A Home Retailer Domain is the domain under the responsibility of the retailer where the end-user has subscribed for service use. This Home Retailer corresponds to the generic Retailer role identified in TINA [iii]. The Visited Retailer is introduced to identify a retailer, federated with the original retailer the user has subscribed to (Home Retailer), which is closer to the actual user location and which can be delegated by the Home Retailer to locally take care of the user.
A fundamental problem to be solved is how to establish a retailer federation and how to select the Visited Retailer, i.e. how to determine which federated retailer, closed to the current user location, can support the user for service access from a remote area. In particular, the choice of the Visited Retailer where to control the service session, has to be done in such a way to result in a performance improvement for both the network and the user. In the following we will investigate these problems, and we will describe how this selection and federation can be achieved: the basis for federation and the way such a federation is established will be explained in Sessions 3 and 4 and the effectiveness of the proposed solution will be evaluated is Sections 5 and 6.

3. Retailer Federation in a Multi-Retailer Environment.

As it has been highlighted in the previous section, retailer federation is a fundamental issue for service deployment in a multi-retailer environment.

According to [ii], we can identify some fundamental principles which are the basis for retailers' federation, i.e.:

1. mutual agreement between retailers for interaction principles, sharing of resources, charging principles etc.;

2. decentralisation, implemented as the responsibility of each retailer to autonomously administrate his objects involved in federation, without any centralised administering entity;

3. transparency, implemented through a Common Shared Knowledge (CSK), which allows information belonging to one retailer involved in federation to be understood and usable in the federated retailer domains;

4. autonomy of partners, which guarantees any retailer to have complete control over resources in his own domain;

5. security, which guarantees each party against unauthorised access to reserved objects.

The last three principles are of particular interest in our specific study, when federation is applied to retailers supporting mobile users. In fact, in order to effectively control service sessions in a domain close to the user location, it is necessary to transfer in such a domain user subscription information, i.e. user profile. In this sense it is very interesting to look at federation transparency, autonomy of partners and privacy to define how federated retailers handle user profiles. In particular, for providing the user with a more effective access to services, according to federation transparency we could consider user subscribed data as part of the CSK. Nevertheless we must consider that, according to autonomy of partners and security, user subscribed conditions are, in principle, data which have not to be shared since they constitute important and reserved information which should not be let to be handled by competitors. According to these last principles, in [ii] it is claimed that "... access sessions between users and retailers take place in the home domain, even if the user is accessing a remote domain" and this strategy is clearly in contrast with the strategy of transferring user subscribed data to the Visited Retailer Domain.
A trade-off solution which satisfies both these strategies is not to migrate the user profile only, but to migrate the agent which controls the user profile, together with it, from the Home to the Visited Retailer. In this case autonomy of partners and privacy are guaranteed since, by migrating not only user related data but also the component which accesses them, the Home Retailer maintains control on user subscribed data. The CSK, in this case is represented by the platform used for supporting agent migration.
Alternatively, the autonomy of partners principle can be overcome by a proper agreement between federated retailers and only user subscribed data can be migrated to the Visited Retailer Domain. In this case federation establishment should define how user subscribed data can be accessed and interpreted by the Visited Retailer.

3.1 Retailer Federation establishment and clearing.

According to [ii], federation between retailers can be established both through an “off-line” contract, and through an “on-line” one, with the main differences between them being the duration. Off-line federation contracts are unlimited, whilst on-line ones terminate when the session in which they have been established ends. Basing on this off-line contract the two retailers will establish an on-line federation. During this on-line federation, the federation contract will be negotiated for the specific case, according to the user subscribed conditions.
Federation between the Home and Visited Retailers can take place in order to:

- provide a user with a subscribed service in a seamless, more effective and cheaper way

- allow a user to access a new service offered by a retailer different from his Home Retailer, being supported for this new service by the Home Retailer for a set of facilities (e.g. authentication and billing could be provided by the Home Retailer).

In the off-line federation contract, information about the common goal to achieve have to be specified: the reasons for federating must be defined (for example that it is defined in order to support personal mobility), the termination policy and the shared data. In our specific application, it could be defined if user subscribed data have to be managed by the Home Retailer (agent and profile migration) or if these data will be disclosed to the Visited Retailer (profile migration). In this sense, the basic elements of the CSK could be already defined in the off-line federation contract in order to make more effective and faster the on-line federation set-up on user access.
In order to establish on-line federation between the two retailers the two parties must:

- define the security mechanism for data transfer (encryption keys, etc.)
- negotiate the service characteristics (bit rate, QoS, etc.)
- negotiate the charging principles to be applied.

On-line federation may be constrained by the terms of the off-line federation contract, or by the specific user subscribed conditions, i.e. a specific user profile could be allowed to be transferred from one retailer domain to another, whilst another one could not be allowed to, thus requiring agent migration.
On-line federation is established the first time the user accesses the system from a remote domain. In this case the first step which must be performed is the user authentication and, to this aim, the user access request must be forwarded to the Home Retailer. In order to minimally impact the current TINA architecture, the Home Retailer is supposed to be directly reachable from the remote area where the user is actually accessing the system. After the access request has been accepted by the Home Retailer by checking the information contained into the user profile, the Home Retailer will try to get information about off-line federated retailers which are closed to the actual user location and which can more effectively support him during his remote access to the system. Such information will be provided by a local *broker* [iii], since the broker can provide other roles within a TINA system with information about services or providers they need to reach. After this, on-line federation can take place.
Another problem which has been investigated is when to tear-down such the federation between Home and Visited Retailer. We could relate the on-line federation life-time with the duration of the session in which federation has been established, i.e. we could clear federation on access session termination or on service session termination.
Another case to be considered is to maintain the agent and/or the user profile data in the visited domain until the user does not require an access/service from another access domain such that the Home Retailer chooses a federated retailer different from the previous selected one. This solution presents the advantage of making user profile immediately available when the user opens another service session in the same area.

4. Impact of Multi-retailer Concept on TINA Computational Model: User Agent Visited and User Agent Home

A retailer domain in the TINA computational view [ii], embodies a collection of computational objects. Within the context of mobile computing the agent controlling the user profile, named User Agent (UA), is of special interest.
The UA has been defined as a service independent service component that represents a user in the retailer's domain. It is the retailer domain's end-point of an access session with a user. A set of subordinated objects are associated to the UA in order to maintain:

- the personal user preference for the different subscribed services in the Personal Profile (PPrf)
- the association between the user and the different terminals he is registered on for different services in the User Context (Ucxt)
- the appropriate subscription information and services in the Subscrition Agent (SubAgt)

The UA has been assigned (among others) the capabilities to:

- support a trusted relationship between the user and the retailer;
- act as a user's single contact point to control and manage the life-cycle of service sessions;
- create a new service session;
- join in an existing service session;
- provide access to a user's contract information with a retailer (user profile).

The UA is therefore that object which can provide the user with a seamless and cost effective service access independently of the terminal and the domain he is accessing from.
The UA introduced by TINA has been defined as accessible by the user, regardless of the user's location. This means that, while a user is roaming, it is always the UA maintained in the retailer domain of subscription (Home Retailer Domain) which represents the user inside the network.
But, as it has been introduced in Section 2, in order to provide the user with a more effective and cheaper access to services, it is more convenient to have an UA representing the roaming user in a retailer domain (Visited Retailer Domain) which is closer to the user's actual location with respect to the Home Retailer.
As a consequence two kinds of UAs can be identified, namely:

- User Agent Home (UAH)
- User Agent Visited (UAV).

The UAH represents a user in the retailer domain in which the user is contractually subscribed. It is created at subscription time and it exists until the subscription is cancelled. Only one UAH exists for a user. The UAH maintains the subscription information and personal user information together with references to all UAVs created in the Visited Retailer Domains.
The UAV is active in the retailer domain closer to the actual user location after a federation between this retailer and the Home Retailer has been established. The UAV will represent the roaming user inside the system. It contains a part, or the entire user profile. After an UAV is present in a Visited Retailer Domain, it is assigned the capabilities of the TINA-compliant UA. More than one UAV can exist at the same time in different retailer domains providing different services to the user and being federated with the user's Home Retailer.
As it has been said, depending on the characteristics of retailer federation, different alternatives can be adopted for what concerns control of user profile in the Visited Retailer Domain. Depending on them three different strategies exist :

1. The UA, including the User Profile, migrates to the Visited Domain.

2. Only the User Profile migrates and a local UA is created in the Visited Domain.

3. The UA, including the User Profile, is maintained in the Home Domain.

Each of these possible alternatives has its pros and cons.
The first allows the retailer with which the user has subscribed to maintain control of user-related data in a remote domain. The disadvantage of this approach is to require a suitable platform for agent migration. In this view this approach can be regarded as a matter of service customisation where the proper UA migrates close to the user's current location [iv], in order to allow the user to access the required service according to the subscribed characteristics. Mobile agent applications can therefore support the user with the capability to associate himself with different terminals for different services. Through UA migration, the user is provided with a customised interface to the specific service he is registered for on the specific terminal. In this way the user can access the service from any terminal according to the characteristics subscribed with his provider, provided that it is compatible with the terminal and network capabilities.
In the second alternative control of the user profile is exercised by UAVs created in the domains where the user is active. In this case the UAH can be considered as simply resulting in a database maintaining pointers to UAVs created in the Visited Domains and the control of user related data is delegated to the Visited Retailer.
The third alternative, is that one defined in [ii] and is the opposite of the first one. In fact, by maintaining and controlling data in the original domain, no transfer is necessary, but a continuous interaction with the

retailer where subscription has been made is required.
In order to compare the effectiveness of the above strategies, the signalling traffic load they cause on the network and the service response time they provide to the users have to be evaluated. A method for the evaluation of these performance features is described in the next sections.

5. Effectiveness of UA migration: the signalling load analysis

In this section we evaluate the effectiveness of the proposed solution to have an UAV in the retailer domain where the user is actually roaming by calculating the signalling load generated by personal mobility procedures when the UA and the user profile migrate from the home domain to the visited one (Migration strategy: M), and when they are maintained fixed in the home domain (No Migration strategy: NM). As the proposed analysis mainly depends on the amount of data which have to be moved through the network, the second alternative presented in Section 4 can be treated as the one in which both agent and profile migrate by considering the load due to the profile migration only.
The evaluated signalling load is associated with those personal mobility procedures [v,vi] which most interact with user profiles. In addition, the Domain update procedure will be considered since the migration from one domain to another plays a main role in our study.
The expression for the total signalling load T in a service session, for both strategies, can be represented by the following formula:

$$T = \sum_{k \in A} \lambda_k T_k \qquad (1)$$

where :

A={the set of personal mobility procedures + Domain Update}= { User Access Session, Start Service Session, End Service Session, Incoming Service Session, User Registration, User Remote Registration, Domain Update }

λ_k= procedure-k requests rate in a service session for a generic user

T_k= total signalling load due to the procedure-k

Obviously, T_k will assume different values according to the two strategies.
In order to evaluate equation (1) a single service session is considered. This means that $\lambda_k = 1$ for k∈{User Access Session }.
For what concerns the procedure-k rate λ_k for k∈{Domain Update}, let us note that it depends on the user mobility model. Assuming, as in [vii], that users are moving at an average velocity of ν, that their direction of movement is uniformly distributed over [0,2π], that they are uniformly populated with a density of ρ and the registration area boundary is of length L_{la}, the rate of domain area crossing, i.e. the Domain update procedure invocation rate, is given by the following expression:

$$\lambda_{\text{Domain Update}} = (\rho\ \nu\ L_{la} / \pi)\ P \qquad (2)$$

where :

P is the probability of being in a boundary location area.

The probability P can be evaluated, according to the above assumptions, by assuming a uniform probability distribution for the user position over all the location areas.
The value of λ_k k ∈ { Incoming Service Session, Start Service Session, End Service Session, User Registration, User Remote Registration} has been considered as variable, in order to evaluate the convenience of the migration strategy.
In order to evaluate T_k, for both NM and M strategies, the personal mobility procedures under study have been described in terms of Message Sequence Charts [v], thus identifying both the messages that flow between the various Computational Objects which act in these procedures and the length in bytes of these

messages. Moreover, a given Service Network Configuration (i.e. allocation of Computational Objects to service nodes) have been fixed [viii], in order to identify which messages contribute to the signalling load across different domains, which messages contribute to the signalling load between different nodes within the same domain and which can be neglected because exchanged between elements within the same service node. Let us stress that the amount of signalling load that crosses different domains is of particular importance, as it more frequently makes use of long-distance signalling links, which are more expensive resource. Finally, T_k, for the personal mobility procedure k, can be expressed as:

$$\mathrm{T_k} = \sum_{i=1,N_k} M * a^k{}_i + \sum_{j=1,P_k} I * b^k{}_j + \sum_{y=1,R_k} E * c^k{}_y \qquad (3)$$

where

N_k is the number of signalling messages exchanged between objects within the same node in the procedure-k;

P_k is the number of signalling messages exchanged between nodes within the same domain in the procedure-k;

R_k is the number of signalling messages exchanged between nodes located in different domains in the procedure-k;

M is the weight associated with a message exchanged between two objects within the same node (in the following, M will be considered equal to 0);

I is the weight associated with a message exchanged between two nodes within the same domain;

E is the weight associated with a message exchanged between two nodes located in different domains;

a_i^k is the number of bytes of the *i*-message exchanged between two objects within the same node in the procedure-k ;

b_j^k is the number of bytes of the *j*-message exchanged between two nodes within the same domain in the procedure-k;

c_y^k is the number of bytes of the *y*-message exchanged between two nodes located in different domains in the procedure-k.

It must be noticed that the value of c_y^k depends on the amount of user related information, that is on UA and/or user profile size. This is an important parameter in our study. In fact, the convenience of the migration strategy depends on it. For this reason, in our analysis, c_y^k will be assumed as variable.

The values assumed by a_i^k , b_j^k c_y^k are evaluated without making any assumption on the control fields added by the protocol in the underlying transport network. Moreover, as different domains are involved in our study, we evaluate this expression by assuming users to be equally distributed over all domains; this allows us to address a single domain D where incoming, outgoing services, registration and domain updating procedures are generated by users visiting D, as well as by users subscribed in D and roaming in another domain.

5.1 Results

The calculations performed according to the method described in the previous section result in the graphs in Figures 1 and 2 where the signalling loads generated by the procedures under study are evaluated according to the NM and M strategies. They show a comparison between the two signalling load, when the size of UA and/or related user profile size is of 500 and 5000 bytes respectively. The signalling load T is calculated vs.

the number of activated procedures within a session. In particular, as far as the number of invoked Domain update procedures is concerned, we have assumed the density of users ρ= 150/sq.mile, the speed of mobile users ν = 50 m.p.h., the location area perimeter L_{la} =20 miles, the probability of being in a boundary location area P = 0.2.

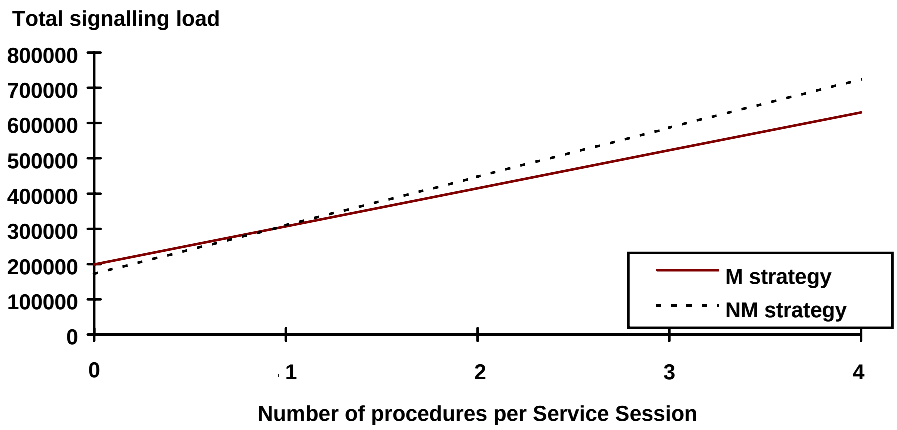

Figure 1: Total Signalling load (user related information size = 500 bytes)

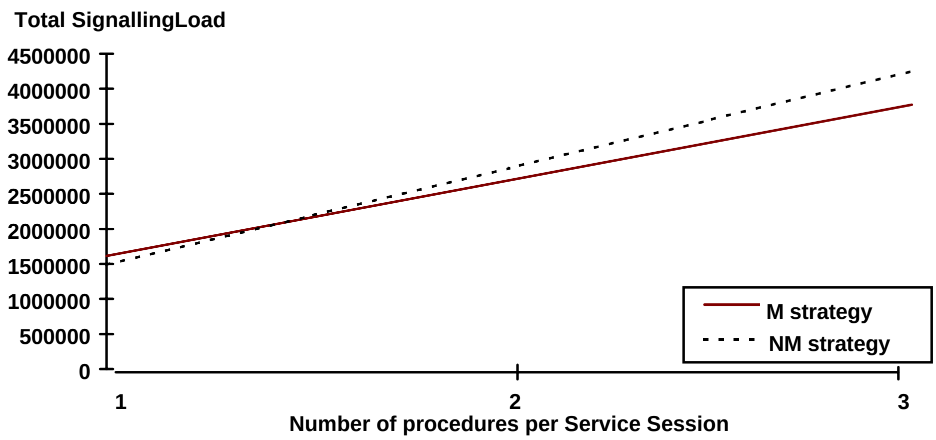

Figure 2: Total signalling load (user related information size = 5000 bytes)

It can be observed that, even with an information size of 5000 bytes, when the number of procedures required is greater than 1, it is still convenient to migrate UA to the Visited Retailer Domain. Similar results were also obtained for larger information sizes. For example, with 10000 bytes, UA migration turns out to be convenient for a number of procedures greater than 3.

Extended to a wider range of user related information size, the above analysis produces the graph shown in Figure 3, where the convenience region for agent migration is identified by the shadowed area.

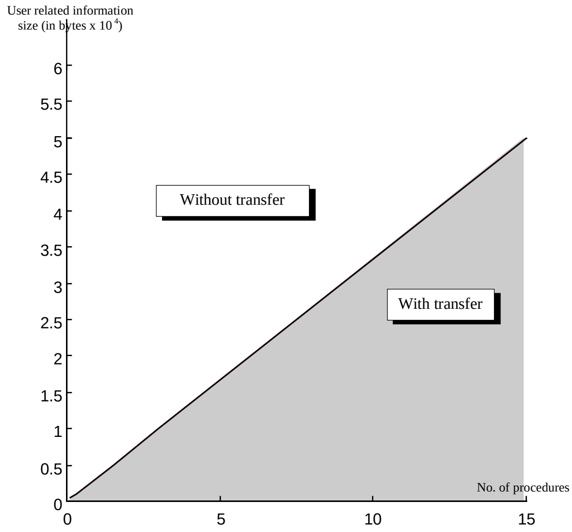

Figure 3: Convenience regions for UA migration

6. Effectiveness of the UA migration: the service average response time.

According to the results shown in Section 5.1 we could state that UA migration is convenient, in the most of cases, with respect to the signalling load on the network. However, migrating UA every time the user moves to another retailer domain, can result in load imbalances among the user nodes, particularly when there are hot spots in the network. In this case the average response time for a service request could be unacceptable due to the too high number of UAs on the user node and, as a consequence, the migration strategy could be not advantageous. Therefore, in order to more deeply evaluate the convenience of the migration strategy, in the following we will compare the average response time for a service request in both the NM strategy (T_{NM}) and the M strategy (T_M).

To this aim, we assume that service requests arrival process in a node is modelled by a Poisson process with an average rate λ. We further assume the service processing time in a node is exponentially distributed with mean value $1/\mu$. Moreover, in the hypothesis of fixed UAs, we can also reasonably assume that UAs are evenly divided among the user nodes, thereby balancing the processing load on these nodes.

Under these hypotheses the average response time in a generic user node is, for NM strategy:

$$T_{NM} = n \cdot t_p + 2 \cdot h \cdot t_i = n \cdot \frac{1}{\mu - N \cdot \lambda} + 2 \cdot h \cdot t_i \qquad (4)$$

where

n = average number of elementary operations for a service request

t_p= average waiting time in a node for an elementary operation

h= number of intermediate nodes

t_i = average time for processing a routing request in an intermediate node

μ = service rate.

N = number of users

λ = service request arrival rate

It should be noted that T_{NM} results from the sum of the average response time on the user node modelled, according to the previous assumptions, as an M/M/1 queue, and the time for the service request to be routed towards the home node. The routing time depends on the number h of nodes which are crossed before reaching the user node in the Home Retailer domain, i.e. on the distance between the visited and the Home Retailer domain. In particular, since for any request routed towards the home user node there is an answer

back towards the roaming user, the average time for processing a routing request in an intermediate node must be considered twice as it is shown in (4).
Let's now focus on the average response time T_M in case of migrating UAs. In this hypothesis the number of UAs on each user node, varies according to the user mobility model. As a consequence, in this case the average response time is :

$$T_M = \frac{n}{\mu - L\lambda} \qquad (5)$$

where n, μ have the same meaning as in (4), but here the arrival rate for service requests is $L\lambda$, L being the number of UAs on the visited user node. In (5) no overhead for routing the request to the node is included since we assume the UA transferred in the user node closest to the actual user location.
The evaluation of the effectiveness of the proposed solution for UA migration in the visited domain can be done through the study of the T_{NM} / T_M ratio, that is :

$$\frac{T_{NM}}{T_M} = \frac{\mu - L\cdot\lambda}{\mu - N\cdot\lambda} + 2\cdot h\cdot t_i \cdot \frac{\mu - L\lambda}{n} \qquad (6)$$

Every time such a ratio will be greater than one, this means that, with respect to the average response time, UA migration is convenient.
The above analysis is done with respect to a generic UA_i in order to decide if it is convenient for the user i to migrate UA_i, with respect to the service response time. But it must be considered that, by migrating a new UA_i in a user node r, the response time averaged on all the UAs on that node increases due to the load caused by UA_i, thus making worse the average response time for the other UA's which could have been previously migrated on the node r for getting better service response times. Therefore when a user requests for a new service session when he is roaming in a remote domain, the Home Retailer, in order to decide if to migrate the UA, after evaluating the T_{NM} / T_M ratio for that user, has to compute the ratio:

$$\overline{T}_{NM} / \overline{T}_M = \sum_{i=1,L+1} T_{NMi} \Big/ \sum_{i=1,L+1} T_{Mi} \qquad (7)$$

where
T_{NMi} = average response time in case of fixed UA for the user i
T_{Mi} = average response time in case of migrating UA for the user i
L = number of UAs already present on the node

in order to guarantee the effectiveness of the migration strategy with respect to the response time averaged on the all users.

6.1 Results

With respect to a single user, it is interesting to study the system behaviour, when the distance h between the home and the visited node and the number of UAs L are varying. So doing, in fact we can find which are the values of the distance from the home user node and of the load on the visited node for which UA migration is convenient. To this aim, in the following we present the results obtained through some significant case studies based on equation (6). In order to obtain these diagrams we fixed the average number of UAs N=100, the average time for processing a routing request in an intermediate node ti= 15ms. and the average number of elementary operation for a service request n=5.
In particular Figure 4 plots the T_{NM} / T_M ratio against the number of mobile agents L, already present within the visited user node for different values of h. It can be noticed that the migration strategy, which obviously is as much convenient as the number of intermediate user nodes grows, still performs well when the load on the visited user node is much higher then its average value N. In particular it can be observed that, even for h=2, the average response time ratio is greater than 1 until the number of mobile UAs is more than 1.5 times average value N (L=150).

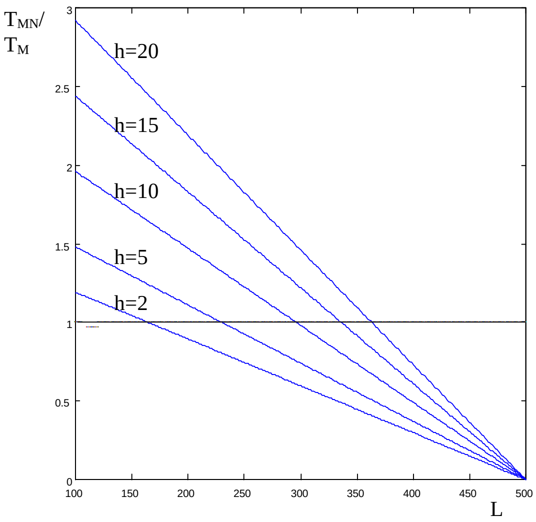

Figure 4: T_{mn}/T_m ratio vs number of mobile agents within the visited user node

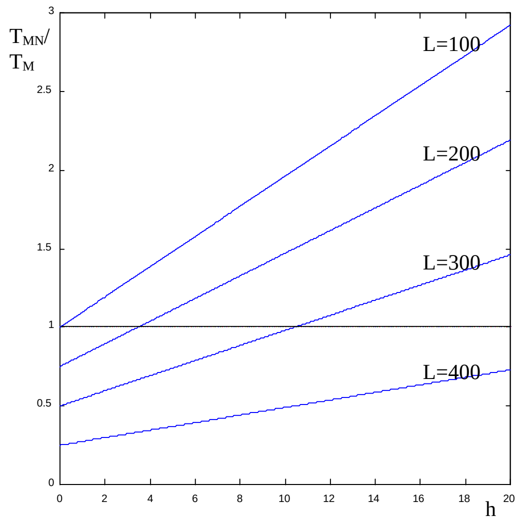

Figure 5: T_{mn}/T_m ratio vs number of intermediate nodes between the home and the visited user node

Also the results of Figure 5 plotting the Tmn/Tm ratio vs number of intermediate nodes between the home and the visited user node confirm our hypothesis with respect to the UA migration. In fact, even in case of a limited number of intermediate nodes between the home and the visited user node, when the load on the visited node is more than 2 times its average value N (L=200), the average response time gives better performances in case of migration.

7. Conclusions

In this paper some issues which are relevant to the support of PCS in a multi-domain environment have been analysed. In particular the TINA Service Architecture has been used as a reference framework in order to show how UAs, representing the user in the domain of subscription, can be migrated from one domain to another to provide the user with a seamless and cost effective access to subscribed services. To this aim, the concepts of Visited and Home Retailer Domains have been introduced and aspects related to this migration have been investigated in view of a "retailer federation" which should be envisaged in the perspective of wide, efficient PCS support.
In order to assess the proposed solution, an analysis of the effectiveness of migrating UAs to the Visited Retailer Domain has been carried out by evaluating two different metrics: the signalling load generated on the network by significant personal mobility procedures and the average response time for service requests. The results adopting both metrics have demonstrated that UA migration is convenient in the majority of the analysed cases.

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