NOMAD: Integrated Networks for Seamless and Transparent Service Discovery

Panos Philippopoulos[1], Pavlos Fournogerakis[1]
Ioannis Fikouras[2], Nikolaus Fikouras[3], Carmelita Görg[3]

[1]OTE Consulting S.A., 32 Kifissias ave., Maroussi, GR-151 25, Athens, Greece,
Tel: +30 10 6879744, email: {PanosPh ; pfour}@oteconsult.gr

[2]BIBA, Bremen, Germany

[3]ComNets, Universität Bremen, Bremen, Germany.

ABSTRACT

The main objective of the NOMAD* project is to develop and demonstrate middleware capable of seamlessly integrating available and future heterogeneous and homogenous network technologies (i.e. UMTS, HiperLAN2) as well as Internet-compatible, multi-hop ad-hoc networks into a single integrated network platform. Innovative technologies, like mobility between devices and new algorithms for parallel usage of multiple access interfaces, are an essential part of NOMAD. Further, NOMAD will support transparent service discovery and provision over integrated networks by means of an intelligent service location and configuration middleware mechanism. It will enable users to locate resources and services within their physical and network environment regardless of the underlying network technology. Special focus of the service discovery process will be on the integration of user profiles and positioning information.

I. INTRODUCTION

Significant technological advances are taking place in recent years in the areas of palm-sized computers and wireless communications, accompanied by an infiltration of the Internet in all aspects of our lives. Consequently, technologies that allow the integration of existing and foreseen heterogeneous and homogenous networks into a single platform capable of supporting seamless user roaming between them will be of major importance. Nevertheless, the rapid growth of the Internet user base has not been accompanied by an equivalent evolution in the corresponding products and services for mobile customers. Existing systems do not maintain the capacity to adapt to changes in the user's location and preferences. It is understood that such services can only be realised through assistance of advanced positioning mechanisms determining the physical location of the user. However, the evaluation of this information is rarely enough for the resolution of service discovery services, mostly because there is no direct correspondence between the virtual (Internet) and physical (real-world) space. The NOMAD project is looking into the aforementioned issues from an integration perspective, i.e. a trade-off between promising innovation and market realism.

This paper is organized as follows: Section II describes the Integrated Network Platform including a number of issues, which need to be addressed. Section III deals with transparent Service Discovery and Provision on Integrated Networks. Section IV describes the concept for integrating User Profiling, Personalization and Positioning Data in Service Discovery and thus adding value to the NOMAD platform. Relevant background is presented and compared to the NOMAD approach. Finally, initial conclusions are drawn and acknowledgements are made.

II. INTEGRATED NETWORK PLATFORM

The lack of considerations for mobility management in the original Internet Protocol design indicate that a mobile node would be reachable only as long as it remained within the boundaries of a given IP administrative domain (IP network). Should a mobile node change its point of attachment to another IP network, it would remain unreachable by all communication peers until it returned to its home environment. This significant restriction forces users to remain under the influence of a single service provider, or network technology (i.e. GSM), in spite of utilizing mobile, or portable devices. However, the availability of wireless and wire-line communication media will continue to increase accompanied by a plethora of access devices. In addition, the turn of operators towards license-free frequencies [1] and their eventual congestion will lead to the realisation of alternative dynamics based on the common convention that users may utilise one another's resources to mutually form a dynamic network structure. This solution poses as a low-cost, high-complexity alternative to conventional systems, one that will dictate a significant shift in complexity from the network towards the end-devices. This will give rise to a new generation of user equipment with several access interfaces allowing simultaneous connectivity over a

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range of providers and technologies. In this environment of multiple providers and access media, NOMAD aims to provide a middleware that allows the integration of IP network technologies into a single platform capable of supporting user roaming between them.

Moreover, the wide range of access devices will dictate the decoupling of users from the terminal equipment, be it mobile phone or PC. In that case, users will be able to roam between devices, even while communicating, without interrupting active connections. This will enable them to take advantage of the full capacity of each access device to increase efficiency and in a manner that matches their individual preferences. Moreover, it will provide the means for remaining always reachable (ubiquitous communication), as any available device in the vicinity of the user could be deployed to perform personal communications without further customisation.

However, as the original Internet Protocol design did not include such considerations, any of the above-described cases would cause a violent break of all active communications. A solution to the problem of Internet Mobility Management is provided through Mobile IP. For the issue of switching between devices while communicating, Mobile IP (in either IPv4 or IPv6 context) may be used to maintain a single point of attachment to the Internet, after a switch between access devices has been effected. However, further changes are required that involve: issuing a new process on the new device capable of undertaking the communication; transferring the state of the communication from the previous to the new device; adapt the communication at both ends and adapt the content to match the capabilities of the new device. That is, transferring a communication between a television and a mobile phone, as the user is leaving its house, might require the renegotiation of the content format as the new device might be unable to maintain the service provided by the previous one.

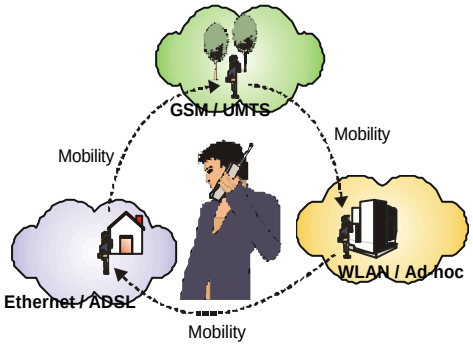

Figure 1 - Integrated Network Platform

Security related issues at network level will also be investigated in order to determine how this technology may affects service discovery and determine potential extensions. Within the above context, NOMAD targets:

- Development of a transparent solution in the form of middleware based on IP mobility and the upcoming IETF standard for ad-hoc network support that will enable the realisation of an integrated network platform which will incorporate every available wireless (e.g. GSM, GPRS, UMTS, IEEE802.11a/b, HiperLAN2, et.) and wire-line access technology that is able to support Internet services. The usage of industry standards is imperative to ensure highest compatibility and industry acceptance.
- Investigate new algorithms for efficient manipulation of available access interfaces with respect to user profile and active communications. That is, for the resolution of multi-media services, preference should be given to the interface with properties that best support the application.
- Investigate how mobility between devices while communicating can be realised based on the current Internet specification. The focus will be on determining in which ways the original protocol design needs to be extended.
- Evaluate existing proposals for Internet compatible ad-hoc networking and determine how such organisations can be included in future integrated network platforms.
- Location-assisted Mobile IP handovers: Currently, Mobile IP handovers are managed by mechanisms (movement detection methods) [2] that are based either on the evaluation of the received wireless signal quality, or on periodic advertisements (beacons) that are broadcasted by Mobile IP mobility agents. Each of these mechanisms is associated with a given period of network service disruption. Within the boundaries of NOMAD, that assumes the existence of location information, alternative Mobile IP handover mechanisms will be studied that involve assistance by location functionality.

III. TRANSPARENT SERVICE DISCOVERY & PROVISION

Integrated networks as a conglomeration of a range of heterogeneous access networks (terrestrial & satellite, mobile & fixed, wireless & wire-line, symmetric & asymmetric, public & private) have certain characteristics that, on one hand offer new opportunities, but on the other impose new restrictions and make use of established service discovery technologies. Such platforms are composed of multiple technologies with very different basic features. Given the fact that integrated platforms present a seamless facade to the user regardless of the nature of the underlying layers, it is easy to assume that applications will not have to distinguish between different networks any more and that arbitrary services will be reachable ubiquitously. This however is not the case even under the unifying blanket of the Internet Protocol.

A major issue with integrated network platforms is in fact, that different segments of such a platform that happen to operate on different network technologies effectively constitute different Internet administrative domains that are termed into this document as planes [3]. Two users standing in the same room accessing the network via different planes may need to traverse vast ranges of Internet fabric in order to reach each other. That is, two neighbouring points in the physical world can be as removed from one another as possible in the

Internet. This effectively demonstrates the discrepancy between the virtual world of the Internet and the physical world. A major requirement of service discovery on integrated network platforms is therefore the transparent bridging of the gap created by the discrepancy between locations in the physical world and locations in the virtual world of the network.

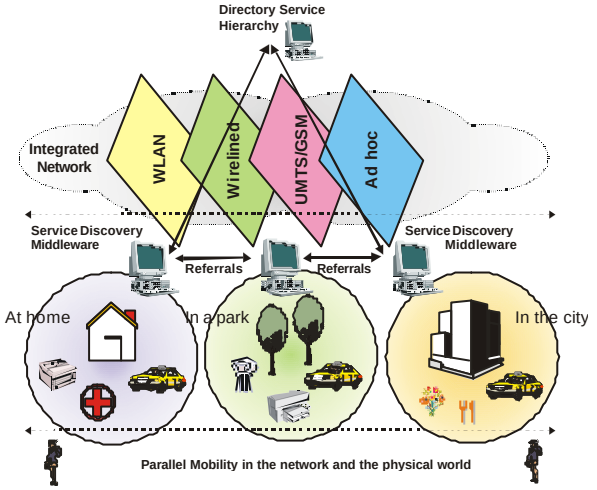

Figure 2 - Different Planes of Integrated Networks

The implementation of a realistic solution capable of achieving widespread acceptance depends on the adoption of widely accepted standards as building blocks. Internet standards in this area providing mechanisms relevant to service discovery include the Service Location Protocol (SLP) [4] (see Figure 3), the Lightweight Directory Access Protocol (LDAP) [5] and the Dynamic Host Configuration Protocol (DHCP) [6] all of which operate on different layers. These protocols cover basic requirements of service discovery such as a means to specify the required service and formulate queries as well as ways for locating and communicating with the appropriate SP. Service discovery functionality as specified by these protocols however focuses on Intranet resource discovery.

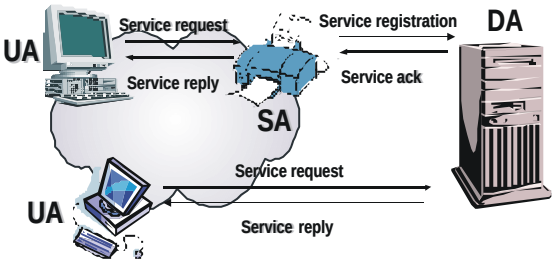

Figure 3 - User Agents (UA), Service Agents (SA) & Directory Agents (DA)

The actual discovery of the requested services is accomplished in two separate ways, either by directly contacting a known address that can supply the client with information on the available services (LDAP), or by broadcasting. Broadcasts can be either focused on the local network (DHCP), or use mechanisms like multicast (SLP) to reach a much larger group of service agents without the need for predefined addresses. The later is a solution with clear advantages in a scenario whereby mobile clients constantly move from one physical location and segment of the integrated platform to another, thus also changing their access point within the integrated network platform and thus constantly in need of updating their information on the available services. A major disadvantage of broadcast solutions is that they can cause enormous amounts of overhead traffic that grow exponentially with the number of hops (Time To Live, TTL) broadcast is allowed to make (i.e. the number of networks it is allowed to flood). Furthermore such broadcasts are necessary every time the mobile node changes its environment (i.e. after a handover), or in some cases every time a certain service is desired. Small TTLs on the other hand reduce the amount of signalling traffic generated, but coupled with the aforementioned discrepancy between the networked and the physical world, can lead to inefficient service discovery queries. Even clients and service providers in close physical proximity are not guaranteed to find each other, due to potentially large "virtual" distances separating them in the networked world.

Another important issue regarding service discovery is the query mechanism used to extract the desired service from the set of available services in the network. Server based solutions like LDAP offer a rich and flexible query language that can be used to formulate very complicated and elaborate requests [7]. Last but not least, a solution implementing transparent service discovery must provide users with adequate protection from push-type unsolicited service offers, or requests.

A number of technical issues will be addressed before integrated networks and services can be provided. The following functions are to be considered:

- Investigate and facilitate the integration of Directory Agents and Directory Servers into gateways that can communicate with customers, as well as Service Agents, and will allow for transparent service discovery between the different parts of the integrated network platform, through the use of Directory Service Referrals. Also investigate the usage of DHCP as a substitute for SLP when searching for a local Directory Server.
- Investigate ways to extend and improve Referrals (see Figure 2) for usage in the integrated network platform. Directory Servers acting as Service Discovery middleware, that receive requests from a specific physical location and are connected to one or more networks, could use an enhanced Referral mechanism to communicate with other "local" Directory Servers that serve a different network or physical area to exchange Information on queries and available services. Thus bridge the gap between different physical locations and parts of the integrated network.
- Define and develop new concepts for machine-to-machine communication between client and supplier systems in order to offer transparent service / product discovery and enable the resolution of elaborate service requests (seamless service packages).

- Investigate how mobility between devices influences service discovery and user profile management in order to further reinforce user centricity.

IV. INTEGRATION OF USER PROFILING, PERSONALISATION & POSITIONING DATA

Mobile devices currently offer only little or no personalization / customisation features, thus reducing the advantages and potentials that Internet and communication technologies offer nowadays. The personalisation issues addressed by NOMAD will cover aspects like multi-cultural features, multi-lingual features, multi-modal interaction and positioning data and service related preferences, thus facilitating transparent discovery with a minimum of user configuration. Moreover this user profile should be in a machine-readable standardised format based on appropriate meta-data to facilitate machine-to-machine communication.

Special security mechanisms may be required to allow the operator to safely query and obtain the user terminal position information, to prevent malicious system use. Special care will be taken in this context, to ensure privacy by complying / extending existing standards. This could involve prompt elimination of the positioning data from the system, or other ways to ensure confidential use of the transaction data.

In this respect, the NOMAD middleware will offer the following functionality:

- Language selection: the user may select the language he/she wants to interact with, or the information accessed in a specific language
- Output-selection: Information available to the user can be in several media. For disabled people, the output, or information access can be in the requested modality. In case of a group, the interaction will be dependent on the group's interest.
- Selection of Interest: The users will have the ability to make a selection of interests, e.g. if interested in specific thematic categories they may make a pre-selection to get the appropriate information. This capability can also be extended to enhance services like Program-Selection, i.e. a program determined from a range of options.
- Positioning Data: The system will adapt its information flow towards the user, according to the user calculated position and vicinity.

The area of user profiling is dominated by one increasingly popular Internet standard: The eXtensible Mark-Up Language (XML) [8], which is largely seen as the beginning of a new era in data exchange i.e., the exchange of information / enterprise data between programs and systems.

The importance of localisation as a primary factor for service differentiation and personalisation has boosted the development & integration of positioning systems. There are a variety of localisation methods that can be applied for subscriber positioning. The localisation methods can be classified in self-, remote-, and indirect-positioning, according to the place where the measurements and their evaluation take place [9]. For the-self positioning systems, the handset makes the measurements, the evaluation and finally estimates the position. In the remote-positioning systems, the fixed part of the network makes the measurements and estimates the mobile terminal's position. Finally, in the indirect-positioning systems, the mobile station makes the measurements and transmits them to the fixed network for evaluation. It is noted that for the NOMAD services extremely high accuracy is required. That is, in order for navigation services to be provided, i.e. a service that leads the user to a desired location, an accuracy of 125m is not acceptable. For such services accuracy of less than 10m would be required. Moreover, some of the techniques assume the existence of an infrastructure. In order for NOMAD to realise its fundamental requirement of global roaming, which is essential for travellers, no infrastructure has been assumed. The underlying network platform, as will be shown, has been required to perform vertical handovers between heterogeneous networks and even to participate in infrastructure-less Ad-Hoc networks in order to provide connectivity at all times.

In such conditions some of the location technologies (e.g. time of arrival, time of difference of arrival, angle of arrival, pattern recognition techniques, satellite positioning systems) may not even be applicable.

All techniques except Pattern Recognition and Satellite Positioning Systems assume a certain terrestrial bearer infrastructure, which may not exist given that NOMAD wishes to also investigate pioneer ad-hoc network organisations. Comparing the last two, it can be found that Pattern Recognition does not assume any additional hardware but requires enhanced complexity by introducing the prediction maps (areas and corresponding expected patterns). Moreover, Pattern Recognition does not demonstrate high precision positioning that is required by the NOMAD services. On the other hand, Satellite Positioning requires the integration of corresponding hardware in the Mobile Terminals. However, as will also be shown during the project's lifetime, certain Ad-Hoc routing algorithms also assume such hardware. As such, providing increased roaming capabilities compensates increased hardware requirements. These features make differential GPS the prime candidate for use in NOMAD. The innovation provided by NOMAD in this context will be:

- Investigate a way to profile services, and develop an appropriate meta-data representation for use in mobile service discovery scenarios. Special considerations include integration of mobility and location dependent aspects. The developed language should be open, easy to understand and implement, be both machine and human readable and offer standardised format based on meta-data in order to facilitate machine to machine communication.
- Investigate means for personalised and transparent configuration of products, mobility / location awareness, and one-step access.

IV. NOMAD BUSINESS ISSUES

The integration of existing services in a single package with the help of the technologies developed by NOMAD will be the basis for a whole new generation of mobile eCommerce services and a variety of new business models and business opportunities.

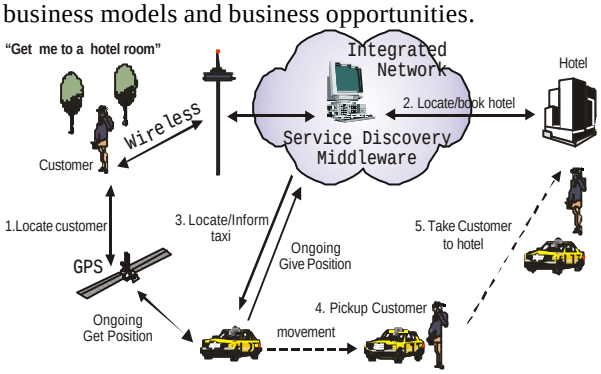

Figure 4 depicts a traveller arriving at a foreign airport seeking accommodation. This person would probably appreciate a full service package that automatically locates a hotel room according to his specification or long standing preferences (service location/profiling). The system should inform the hotel and subsequently locate a taxi informing the driver of the traveller's location and preferred destination. The taxi driver could then pick up the customer and bring him to his hotel. This service would be a very useful service for people trying to find their way around a foreign environment.

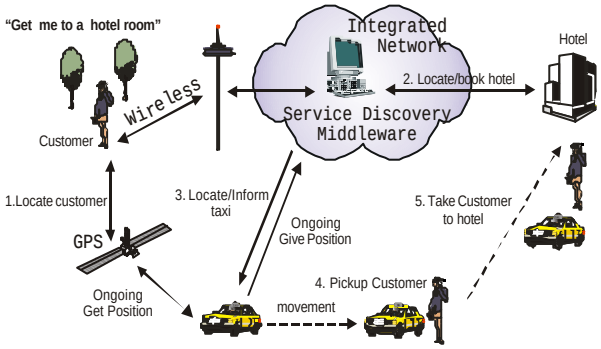

Figure 4 - NOMAD Integrated Service paradigm

The provision of such services to the user will require little activity on his behalf. Both the integrated network platform and the transparent service provision and discovery middleware on NOMAD make sure that all the different entities in Figure 5 can interact transparently to provide the above service:

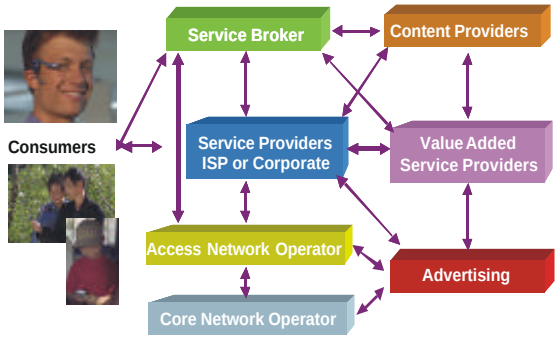

Figure 5

Figure 5 - NOMAD Business Model [10]

V. Conclusions

The NOMAD project deals with the integration of location aware service discovery mechanisms, handover procedures and service / user profiling, by developing technology that allows users to freely roam across existing and future network infrastructures. We analyze the NOMAD Network Platform concept, the methods for transparent discovery and seamless provision of services and the integration of service / user profiles. The NOMAD platform will be available for testing and refining the implemented software during the project lifetime. The overall target of NOMAD is to derive products enabling the integration of existing wire-line and wireless technologies with seamless connectivity and intelligent service discovery provision, increasing user satisfaction and adding value to existing services.

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