Integration of Navigation and Communication for Location and Context Aware RRM

Ernestina Cianca[1], Mauro De Sanctis[1], Giuseppe Araniti[2], Antonella Molinaro[2], Antonio Iera[2], Marco Torrisi[1], Marina Ruggieri[1]

[1] University of Rome Tor Vergata, Department of Electronics Engineering, via politecnico 1, 00133 Rome, Italy
[2] University "Mediterranea" of Reggio Calabria, D.I.M.E.T., via Graziella lo. Feo di Vito, 89100, Reggio Calabria, Italy
Phone: 1 +390672597284, Fax: +390672597455, e-mail: cianca@david.eln.uniroma2.it

Abstract. Next Generation Wireless Networks (NGWNs) will allow the user to roam over different access networks, such as UMTS, Wi-Fi, satellite-based networks. Currently, these networks are integrated/assisted by more and more accurate navigation systems, which can make available the information on the location of the mobile terminal. This information is then typically used to provide location based services. This paper addresses a novel way of jointly using navigation and communication systems: the information on location together with other information on the situation of the user/network nodes is used in order to optimize the mobility and resource management over satellite/terrestrial heterogeneous networks.

1 Introduction

A heterogeneous communication network is foreseen for Next Generation Wireless Networks (NGWNs) where different Radio Access Networks (RANs) such as Terrestrial Universal Mobile Telecommunications System (T-UMTS), Satellite UMTS (S-UMTS) and Wireless LANs (WLANs) can be offered to the user in order to access the same core network. The efficient integration of different access systems is one of the main challenges for the scientific and industrial telecommunications community. In this framework, the new concept that is addressed by this paper is that the deployment of NGWNs may benefit from the capability of exploiting location/situation information for:

- more efficient "seamless" integration of heterogeneous radio access networks;
- improved resource allocation both within one single network and in the integrated heterogeneous scenario.

Some works have already shown that this information can be used to improve radio resource management or mobility management (i.e., horizontal handover) by properly designed mechanisms [1–5]. In this paper, this concept will be further developed. We claim that location information, together with the knowledge of the user situation or context, could become the most important enabling function in order to provide efficient integration of different access technologies.

The paper first presents an architecture able to collect the location/situation information, process it and distribute it to the network nodes that will exploit it to successfully implement location/situation aware radio resource management (RRM) or mobility management mechanisms. Later on, the agent-based middleware implemented in some components of the proposed communication platform is described in details. Finally, possible location/situation aware RRM and mobility management mechanisms are proposed in a heterogeneous network which includes HAPs and satellites. Advantages offered by these enhanced RRM mechanisms and also the limits due to the attainable accuracy of currently available radio-location techniques are discussed.

2 Overview of Radiolocation Techniques

In this paper, the term *location* refers to the geographical co-ordinates of the mobile users and, in some cases, also to the speed, direction and orientation of the users movements. A network control center can process the information about the mobile user location with the aim of computing:

- user location with respect to the cell of coverage;
- user distance from the access nodes;
- path and next location of the user/node.

In satellite-based networks, HAP-based networks and ad-hoc networks, nodes are mobile in nature. Therefore, in such networks, the term *location* can be also referred to the geographical co-ordinates of the *network nodes*. The knowledge of this information could be used to more efficiently manage the dynamics of the network topology, the coverage and also the resource allocation.

Location systems can be classified into physical or symbolic. Physical information provides the position of a location on a physical coordinate system (x,y,z), for example the Electronics Engineering Department is at (x1,y1) coordinates. Symbolic location information provides a description of the location, for example the Radar laboratory at the Electronics Engineering Department. Furthermore, the Symbolic location is related to abstract ideas; physical location information can be derived by symbolic position with additional information. Using only symbolic location information can yield very coarse grained physical positions [6].

An absolute location system uses a shared reference grid for all located objects, while in a relative system, each object can have its own reference frame. An absolute location can be transformed into a relative location.

In indoor location architectures, there are, in general, two different types of mobile devices: active and passive. In an active mobile architecture, an active transmitter on each mobile device periodically broadcasts a message on a wireless channel. On the other hand, in a passive mobile architecture, fixed nodes at known positions periodically transmit their location (or identity) on a wireless channel, and passive receivers on mobile devices listen to each beacon [7].

In the following, we will compare several indoor/outdoor radio-location systems in terms of some parameters of interest for the application considered in this paper.

2.1 Indoor/Outdoor Sensing Systems

Active Badge: it uses cellular proximity system that employ diffuse Infrared technology. The system can locate every person that wear a small infrared badge. The badge emits a globally unique identifier every 10 seconds or on demand [6]. These periodic signals are picked up by a network of sensors placed around the host building. A master station, also connected to the network, polls the sensors for badge ‘sightings’, processes the data, and then makes it available to clients that may display it in a useful visual form. An active badge signal is transmitted to a sensor through an optical path. This path may be found indirectly through a surface reflection, for example, from a wall [8].

Active Bat: this location system uses an ultra sound time-of-flight lateration technique to provide more accurate physical positioning than active badges. Users and objects carry active bat tags. It combines a 3D ultrasonic location system with a pervasive wireless network [6].

A short pulse of ultrasound is emitted from a transmitter (a bat) attached to the object to be located, and the time-of-flight of the pulse to receivers mounted at known points on the ceiling is measured. The speed of sound in air is known, so we can calculate the distance from the bat to each receiver - given three or more such distances, we have enough information to determine the 3D position of the bat (and hence that of the object on which it is mounted) [9].

Cricket: the system is decentralized so that each component of the system whether fixed or mobile is configured independently, no central entity is used to register or synchronize elements. This architecture uses beacons to disseminate information about a geographic space to listeners. A beacon is a small device attached to some location within the geographic space it advertises. To obtain information about a space, every mobile and static node has a listener attached to it. A listener is a small device that listens to messages from beacons, and uses these messages to infer the space it is currently in [10].

Enhanced 911 (E 911): it is used to determine cellular phones location and can be used in applications that need to find the nearest gas station, post office etc. [6].

RFID: the basic premise behind RFID systems is that you mark items with tags. These tags contain transponders that emit messages readable by specialized RFID readers. A reader retrieves information about the ID number from a database, and acts upon it accordingly. RFID tags fall into two general categories, active and passive, depending on their source of electrical power [11].

Most of the applications of RFID technology, however, assume that the readers are stationary and only the tags that are attached to objects or persons move. The main focus is to trigger events if a tag is detected by a reader or entering the field of range [12].

Cell-ID: the cellular based location system is overlaid on the existing cellular communication system. The common geolocation techniques used in cellular-based location systems are signal strength measurements, time of arrival, time difference and angle of arrival [13].

The cell ID only has to be associated with location, i.e. the coordinates of the BSs must be known. In this method, no calculations are needed by the mobile unit to obtain location information [14].

Table 1. Properties of the location sensing systems.

Technology	Technique	Physical location	Symbol location	Absolute location	Relative location
Active badges	Diffuse Infrared Cellular Proximity	No	Yes	Yes	No
Active bats	Ultrasound, of lateration	Yes	No	Yes	No
E 911	Triangulation	Yes	No	Yes	No
Cricket	Proximity, Lateration	No	Yes	Yes	Yes
Cell-ID	Signal strength measurements, time of arrival, time difference and angle of arrival	Yes	No	Yes	No
RFID	To mark the items with tags.	No	Yes	No	Yes
GPS	Radio TOF lateration	Yes	No	Yes	No

2.2 Outdoor Only Sensing Systems

GPS (Global Positioning System): it uses multiple synchronized sources with known locations (satellites) and a single receiver with unknown location to determine a position. Each satellite of a constellation transmits a unique code, a copy of which is created in real time in the user-set receiver by the internal electronics [15]. GPS provides physical position and absolute locations, inexpensive GPS receivers can even determine and locate positions to within 10 meters for approximately 95% of measurements. A minimum of four satellites must be visible for most applications.

DGPS (Differential GPS): the precision of the GPS can be enhanced by means of DGPS which uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions.

Table 1 shows the main features of some location sensing systems where the location system properties are defined.

In Table 2, a comparison of the location sensing systems in terms of accuracy and precision, scale, cost and limitations is provided.

3 Context Managements Techniques

The location information described above can be considered as a part of the user context. The term *context* is referred to a set of parameters that can be used to describe the environment in which the user is embedded, the devices, and the access networks with which the user interacts. To better characterize a user context, we add to the *geographical* user location, which has been previously defined, the *environmental* user location, which includes more information on the specific environment a user is currently located (e.g., stadium, hospital, ambulance, city centre, etc.). Sensor devices can be used to get environmental contextual information. The collection and forwarding of context parameters to the access network is responsibility of the *Context Detector* (CD) entity that will be described in Section V.

Table 2. Comparison of the location sensing systems.

Technology	Accuracy and precision	Scale	Cost	Limitations
Active badges	Room Size, Active architecture	1 Base Station per room, badge per Base Station per 10 sec	Inexpensive	Sunlight, fluorescent interference with infrared, and unsuccessful for many applications that require fine-grained 3D location and orientation information.
Active bats	9cm (95 %), Active architecture	1 Base Station per 100 m, 25 Computation per room per sec	Cheap tags and sensors, inexpensive and low-power.	Required Ceiling grids
E 911	150m–300m, (95 %) of calls	Density of cellular, infrastructure	Cell Infrastructure, Expensive	Only whee cell, Coverage exists
Radar	3 to 4.5 m, (50 %)	3 BSs per floor	802.11 network, installation, Expensive	Wireless NICs required
Cricket	4*4 ft region, (100 %)	1 beacon per 16, square-foot regions inside a room	Expensive	No central, management, receiver
Cell-ID	Depend by cell's topology	Depend by cellular's infrastructure	Expensive for installation the cell's network	Cover based
RFID	Depend by the power usage and used frequency	The read range of RFID is larger than that of a bar code reader	Convergence of Lower cost	The two categories, active or passive, depending on their source of electrical power, it does not require line-of-sight access to read the tag
GPS	10 to 30 meters (95–99 %)	24 satellites world-wide	Too expensive infrastructure	Stricted to outdoors only
DGPS	<1 m	24 satellites world-wide	Too expensive infrastructure	Stricted to outdoors only

The *user profile* (UP) can be used to provide some personal information and preferences about the user and its devices, such as gender, age, and type of user (e.g., business, traveler, private), type of terminal and its status (e.g., supported media, computational capability, battery level/energy resources, preferred screen color, font type). UP can include other information and preferences related to the service level agreement, such as the maximum cost that the user is willing to pay for that service, the residual credit, the target QoS level (hard, soft), the preferred level of security, etc.

During the exploitation of a service, the user is allowed to change his/her UP, which can be stored into one of the user's devices (e.g. in a smart card), or even partly stored in some network databases.

The term *situation* is referred to the interpretation of the physical, social or environmental contextual information that can be referred to the user and/or to the access network. This interpretation requires a set of rules defined (personalized) by the user. These rules can be defined by the user profile. Of course, *situation* is an evolving concept; therefore its description must be continuously updated. The distributed information that characterizes a specific situation (e.g,, network resources, class of users, devices, applications, etc.) must be collected and *dynamically, autonomously*, and *proactively* handled to create a logical representation of the current user's working environment.

4 Architecture Description

In NGWNs the user terminal(s) allows the connection of the user with at least one of the RANs available in a given area. The user terminal can be either an integrated device, or a set of different devices in a Wireless Personal Area Network (WPAN), or a completely reconfigurable terminal. Figure 1 shows the proposed reference scenario, where the user can get connected to the heterogeneous network with the support of three entities: the Location Enabler (LE), the Context Detector (CD) and the User Profile (UP).

The LE is a device with localization capabilities. It can be a GPS receiver or any other device that is able to get information about the position of the user (see section III) and it is able to communicate this information to other terminals by using the Bluetooth technology or any future WPAN standards. In our architecture the LE is represented as a separated device, however, it could be also integrated into one of the other user's devices. Seeing it as a separated device helps to logically

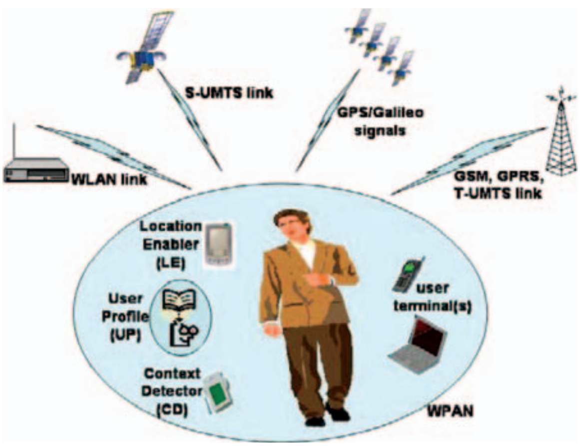

Fig. 1. Reference scenario.

separate its functionality from the communication functionality of other devices in the architecture and to focus on the central role of the location information in this framework.

The CD is an entity responsible of collecting contextual information from the environment surrounding the user. This could mean that the CD has to be able to collect the information from physical sensors (e.g. temperature, humidity or light sensor) or to detect information by itself.

The UP represents a set of personal information which can be partly stored in one of the user devices and is useful for the definition of the situation given a certain location and context. Some variables included in the user profile are almost static and can be stored in some network databases, some other variables are dynamic and can be continuously updated by the user through interaction with the UP module.

4.1 Communication Architecture

This Section defines the main components of the architecture that are able to collect, process and distribute the location/situation information to the user and/or network nodes, in order to use them through properly designed algorithms.

The proposed architecture is shown in Fig. 2 and it consists of different access networks, referred as Slave Networks, which interact through a common platform called Roaming Provider (RP).

Figure 3 shows the components of the RP, which consists of:

- *AAA database*, which stores the agreements of the user with each access network.
- *User profile database*, which stores profiles of the users.

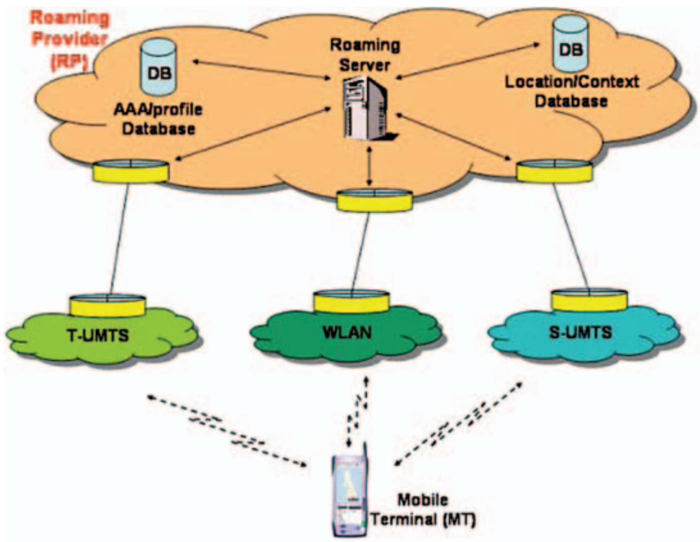

Fig. 2. Communication architecture.

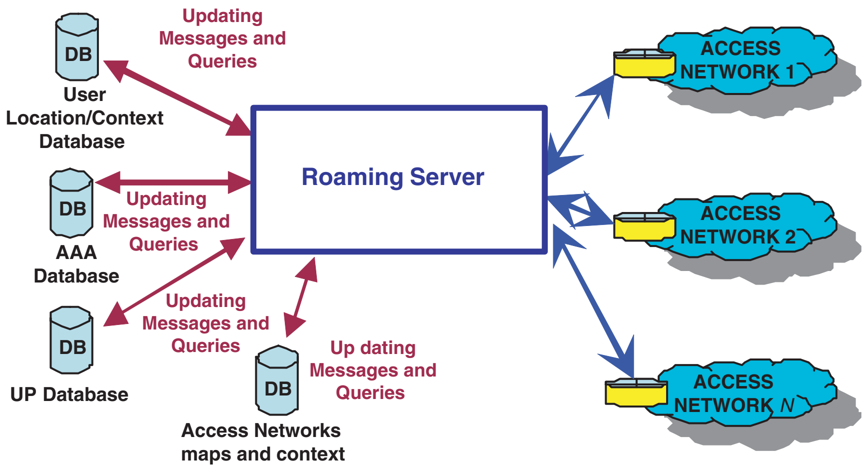

Fig. 3. Roaming provider architecture.

- *User location/context database*, which collects the relevant location/context information of the users in the area covered by the underlying access network.
- *Access network map and context database*, which stores the map and the current context state of the access networks under the control of the RP.

The Roaming Server (RS) processes the information stored in the four databases and sends the results of this processing back to the users/nodes, with two different purposes, which are:

- to achieve the key parameters in input to specifically designed location/situation-based algorithms of resource and mobility management.
- to start vertical handover procedure involving some of the underlying access networks.

The RP must process a number of information that is directly proportional with the number of users and networks available in a given service area. Therefore, it is better to distribute the RP functionality over several interconnected servers. Thanks to its features, a HAP could provide a privileged host for the RP functionality.

4.2 Middleware

We are convinced that in 4G networks, under heterogeneous RANs, several providers, and manifold terminal devices and applications, a multiagent-based middleware platform is a powerful solution to provide global area service management. In this section we describe the agent-based middleware we propose to be implemented in the communication architecture of a Roaming Provider. Intelligent agents have the task to support the user during access network selection, resource and handover management procedures, as well as in service discovery and QoS parameters adaptation procedures.

Our architecture includes five agent typologies: User Agent (UA); Accounting Agent (AA); Network-side User Agent (NUA); Radio Resource Agent (RRA); and Service Agent (SA). They are distributed in the overall architecture as illustrated in Fig. 4. The Databases shown in Fig. 4 represent the repositories illustrated in Fig. 3 for user profiles (*Profile Database – PDB*), authentication information (*AAA Database*), location and context information (*User Location/Context Database – LCDB*), and *access network maps and context database* (ANDB).

The Roaming Provider could either belong to a single operator owning several RANs (e.g., WLAN, UTRAN, satellite master control stations, etc.), or it could be owned by a "third-party" establishing agreements with both the user and a number of operators in order to offer ubiquitous service access. Whatever the choice, the middleware platform will be deployed in a NGWN composed of different RANs and a backbone equipped with a Roaming Server for each Roaming Provider.

The RS functionalities described in Section IV-B can be split in two parts:

- On the network side, there are the functionalities relevant to the *Network Resource Manager* (NRM)
- On the middleware side, there are the functionalities relevant to Roaming Decision Maker (RDM); Information Collector (IC); Location Tracer (LT), and Situation Tracer (ST), that represent some of most important functionalities of the NUA agent.

The proposed middleware architecture is *situation and location aware*, since it reflects the instantaneous changes in the observed scenario. As already mentioned, instantaneous positions are available at the user terminal through the LE device; they will

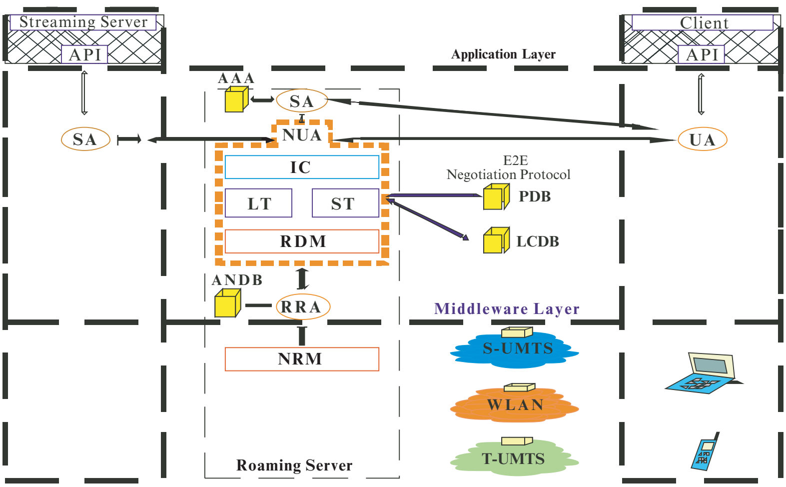

Fig. 4. Middleware architecture.

be periodically signaled to the middleware platform through interaction with the User Agent.

The UA is implemented in the user terminal; it follows the user when he/she is roaming and continuously monitors his/her local context. The UA interacts with:

- the SA, which is involved in a service discovery procedure within the RP's platform;
- the AA, which performs user identification and accounting (AAA functions), and triggers the instantiation of the NUA for the new user in the RP's platform
- the User, in order to manage his/her preferences and to forward them to NUA, which has the task to store them in the PDB. In addition, the UA notifies the user of the decisions taken on behalf of him/her by the NUA after negotiations with other agents in the provider's platform.
- the Application layer in order to individuate the requisites of the application, in terms of both network (QoS) and elaboration (hardware and software) resources, and to communicate them to the NUA. This latter will, then, request the allocation of the necessary radio resources and telecommunication services in the provider's platform.
- the Device, to obtain the information about available network interfaces and their features (e.g., their current status, the received signal strength, etc.)
- the NUA, which represents the user counterpart in the provider's network. Periodically, the UA updates its counterpart with new location information. The update frequency depends on the user speed, the precision and the rapidity the offered service requires this information.

The NUA, typically placed at the middleware layer in the RS, has the task to interact with the UA and with other network-side agents (RRAs and SAs). An NUA will be instantiated for each user who wants to access the provider's platform. The NUA migrates with the user from one roaming server to another each time the user roams from a domain managed by a provider to another domain belonging to a different provider.

The NUA implements the algorithms for selection of both the access network and the available services for the user. Furthermore, as already mentioned, the NUA includes different functional blocks: the IC module is responsible of the reception of location, context and profile information from users and access networks and it has the task to store, update and query this information from the databases. The location information of users and mobile nodes managed by the IC is then sent to the RDM through the LT module.

Moreover, it is the NUA that interprets the context information by using the UP to get the situation information about the user or network nodes by using the ST module.

The input parameters which help the NUA in taking decisions include both historic (almost static) information and more dynamic information related to the user, and also network-related information. They are the following:

- the *historic user profile*, stored in the PDB;
- the *running user profile*, notified by the UA, including current device and requested application characteristics;

– the *network profiles*, signaled by the RRA, which includes information on available access networks status and resources availability obtained by the NRM;
– the *service profiles*, received from the SAs, which include information of the currently available services through the various RANs of the provider's platform.

The SA is the agent with the task of performing service discovery. It delivers the NUA the list of the available services offered by the service providers, which have competence in that location and in that situation. The NUA selects the service for the user based on his/her profile, on the device he/she is currently using, and on the access network situation. According to the NUA choice, the SA has to take care of the service delivery at the right QoS level. This means that it has to take care of the determination and adaptation of the right service configuration both during setup and at runtime.

The RRA is implemented in the middleware layer of the RS and has the task to verify the resources availability at the network layer, across multiple access networks managed by the provider. To this aim, it periodically contacts the NRM devices to verify the resources availability in the various RANs.

5 Location-Aware Mobility Management

In this Section we show an example of location-aware handover mechanism. In particular, we consider the vertical handover between T-UMTS and WLAN: the user is making a call using VoIP with T-UMTS and is approaching a WLAN hot spot area. The handover procedure consists of two phases:

1) detection of a WLAN coverage and activation of the WLAN air interface (activation phase);
2) decision phase about the opportunity of making or not the handover (decision phase).

Both phases exploit the information on the location of the user.

5.1 Activation Phase

Let us consider a user moving at speed ν along the x-axes of a reference plane centered in the centre of the hot spot area of the WLAN. Let us assume that the time needed to "wake up" the WLAN air interface is a couple of seconds. We can then fix a minimum threshold S_{Dmin}, which defines the minimum distance between the mobile terminal and the border of the WLAN spot area at which the Roaming provider should send the message to activate the WLAN air interface. This information can be made available at the NUA through interaction with the UA. This threshold will depend on:

- "wake up" time t_{ris}, which is the minimum time needed by the air interface before the terminal is able to detect the beacon signal of a WLAN. During this time the terminal will move of a distance:

$$D_{ris} = v \cdot t_{ris} \quad (1)$$

- time interval between two consecutive updates of the information on the user location (position, speed and orientation of the movement), denoted as t_{update}. For instance, in case of GPS, t_{update} = 1s. In this time interval the user moves ahead of:

$$D_{update} = v \cdot t_{update} \tag{2}$$

If we do not consider D_{update}, it could happen that the user has already moved into the WLAN area without activating the air interface.

Finally S_{Dmin} depends on the accuracy on the user location information. If we denote with ε the maximum error on the user position, S_{Dmin} can be written:

$$S_{Dmin} = D_{ris} + D_{update} + \varepsilon \tag{3}$$

In Fig. 5 it is shown for different levels of accuracy the value of S_{Dmin} vs. the user's speed. We can observe that by using a GPS with a typical accuracy of 30–10m, S_{Dmin} is already very high with low-average speed (20m/s) with respect to the case of a DGPS, which has a range of 3–0.5m.

Table 3 shows the value of S_{Dmin} for different environments in case of GPS or DGPS localization system. From Table 3 we can conclude that for this application it is important to use some improved GPS, such as the DGPS. On the other hand, Table 3 also shows that for high speeds (i.e., 120km/h) the high value of S_{Dmin} discourages the use of this "wake up" procedure.

In a multimode device enabled to the handover process, the two air interfaces are always waken up, and, hence, a classical handover procedure does not include an activation phase with its activation rule. The advantage of this activation phase is that only one air interface at a time is active, thus decreasing the energy consumption of the multimode device.

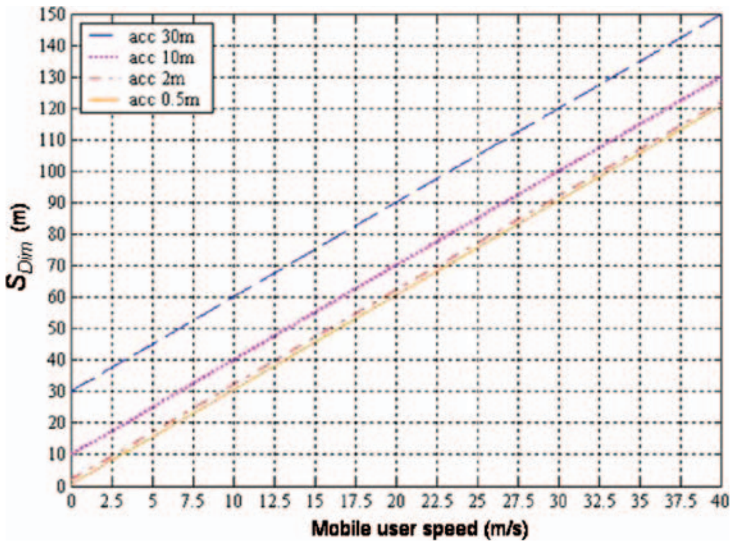

Fig. 5. Minimum threshold vs mobile user speed.

Table 3. Minimum threshold in case of GPS and DGPS for different environments.

	Speed		S_{Dmin}, [m]			
Mobile user speed	km/h	m/s	acc. 30m	acc. 10m	acc. 2m	acc. 0,5m
Pedestrian/indoor	3,6	1	33	13	5	3,5
Urban area	50	13,88	71,64 (72)	51,64 (52)	43,64 (44)	42,14 (42,5)
Urban street at high speed	80	22,22	96,66 (97)	76,66 (77)	68,66 (69)	67,16 (67,5)
Highways	120	33,33	129,99 (130)	109,99 (110)	101,99 (102)	100,49 (100,5)
			GPS		DGPS	

5.2 Decision Phase

The decision phase starts when the WLAN air interface is active and when the mobile terminal probes a WLAN signal with enough strength. Then it sends a message to the Roaming Server (specifically the NUA module), which is responsible for deciding about starting or not the handover procedure. The decision will be made according to a prediction of the average time the user will remain in the hot spot WLAN area. In fact, the handover to WLAN will be effective only if the user will be able to experience the higher transfer rate in the WLAN. However, taking into account the time needed to conclude the handover procedure, which is a period of time with no transmission of data, if the user will stay in the WLAN area for too short, the amount of transferred data could be even less than in the case of not handover at all. Therefore, the decision criteria will be based on the evaluation of the The minimum Required Visit Duration (RVD), which is the minimum time that a user must remain within the same WLAN coverage area to ensure the successful completion of the handoff procedure and the transfer of a sufficient (configured) amount of data over the WLAN network. In other words, it is the amount of time that the user must remain within the same WLAN to allow the application to benefit from the higher data rates and compensate for the handoff-related delays. The RVD can be evaluated by:

$$RVD_{\min} = L_a + (L_c + L_{MIP} + L_s)\ \tau \qquad (4)$$

where:

- L_a is the latency due to one single iteration of the decision algorithm, from the arrival time of the request to the time notifying that the decision has been made;
- L_c is the latency associated to procedure for configuring the address;
- L_{MIP} is the latency related to the Mobile IP operations and the registration phase;
- L_S is the latency associated to the stabilization phase of the connection;
- τ is the period of time needed to receive with the WLAN the same amount of data that would be received with the UMTS connection in the period of time equivalent to the handover delays. τ can be evaluated as follows:

$$\tau = (L_c + L_{MIP} + L_s) \times (R_c / R_t) \qquad (5)$$

where:

- R_c is the maximum data rate serving the user before the handover;
- R_t is the maximum data rate in the network towards the user is moving.

Once the RVD has been evaluated by the NUA, the algorithm must estimate the Predicted Path Length (PPL), which is the distance covered by the user moving at speed ν in the time RVD:

$$PPL = RVD \times v \tag{6}$$

If the user starts to move from a point of coordinates (x_1,x_2), and covers a distance of PPL in the direction θ, he/she will move to the point (x_2,y_2) which are:

$$\begin{aligned} x_2 &= x_1 + \mathrm{b} \\ y_2 &= y_1 + \mathrm{a} \end{aligned} \tag{7}$$

where:

$$\begin{aligned} a &= PPL \times \sin(\theta) \\ b &= PPL \times \cos(\theta) \end{aligned} \tag{8}$$

Therefore, the NUA queries the *access network maps and context* database containing the map of the hot spot area, and checks if the new coordinates fall into the WLAN area. If so, then the NUA will activate the handover procedure, otherwise the handover will not take place.

One of the main limitation of this algorithm is related to the value of L_a, which must be kept as lowest as possible. A high value of L_a results in a high value of RVD, which could mean that the handover towards the WLAN has a low probability to happen, even if it is beneficial to the user. The value of L_a is mainly related to the localization information acquisition time. A high value of L_a could be due to the obstruction of the satellite in a GPS localization system. However, if the value of L_a is updated each time a new position is detected, any wrong decision in the algorithm will not persist for a long time.

6 Radio Resource Management

This Section provides some examples of the use of the location/situation information about the user and/or network nodes in RRM mechanisms.

The knowledge of the location of users and access network nodes can be important for the optimization of the RRM when the access network nodes are mobile and the distance between the user and the access node varies in a wide range, which is the case of satellite and HAP networks.

In such networks, the knowledge of the users and nodes location can be used to aid handover, scheduling, power control, call admission control, etc. For instance, scheduling mechanisms could give priority to users in specific geographical positions with respect to other users for different objectives (reducing the experienced delay, reducing the congestions in some areas etc.). More in general, location/situation awareness can be used to guide a mobile user from a bandwidth-impoverished to a bandwidth-rich environment. In a heterogeneous scenario, where more than one access network is available, the user can choose the best solution according to its position, its preferences (user profile) and the specific context. Assuming that each Roaming Provider controls different RANs, the task of efficiently control the assignment of resources in the various RANs can be performed in a distributed and cooperative way by the RRA agent, the NRM and RDM modules in the Roaming Server. Areas managed by an RRA can coincide with one access network, or be a part of a network, or even they can include more networks. Thereby, the resource management functionality in the Roaming Provider's platform can be performed by a unique RRA agent or more agents (typically one for each access network).

7 Conclusions

This paper proposed a middleware-based architecture to perform efficient location/situation aware mobility and resource management mechanisms in future heterogeneous networks. In particular, one location/aware vertical handover mechanism is presented where the location information plays a key role in both the phases of the handover algorithm: "wake up" of the air interface and the decision phase. The example shows that the accuracy and the update time of the information are of key importance. The accuracy and the update time of current localization systems already made possible the use of the proposed algorithms in many cases (i.e., user speeds). However, to make cost-effective the implementation of the proposed location/situation aware mechanisms, they should be further improved.

References

[1] C.A. Patterson, R.R. Muntz, C.M. Pancake, "Challenges in Location Aware Computing", IEEE Pervasive Computing, pp. 80–89, April-June 2003.
[2] S. Sharma, A.R. Nix, S. Olafsson, "Situation Aware Wireless Networks", IEEE Communications Magazine, pp. 44–50, July 2003.
[3] D. Jeong, Y.G. Kim, H.P. In, SA-RFID, "Situation-Aware RFID Architecture Analysis in Ubiquitous Computing", Proceedings of the 11th Asia-Pacific Software Engineering Conference (ASPEC 04).
[4] Jian Ye, Jiongkuan Hou, S. Papavassiliou, "A Comprehensive Resource Management Framework for Next Generation Wireless Networks", IEEE Transactions on Mobile Computing, vol. 1, no. 4, pp. 249–264, Oct.-Dec. 2002.
[5] Siamak Naghian, "Location-Sensitive Radio Resource Management in Future Mobile Systems", WWRF Results of NG4 May 10–11, 2001 of NG4 May 10–11, 2001.
[6] J. Hightower, G. Borriello; "Location systems for ubiquitous computing.", IEEE Computer, Volume 34, Issue 8, pp. 57–66, Aug. 2001.
[7] A. Smith, H. Balakrishnan, M. Goraczko, and N. Priyantha; "Tracking Moving Devices with the Cricket Location System.", MIT Computer Science and Artificial Intelligence Laboratory, http://nms.csail.mit.edu/cricket/
[8] R. Want, A. Hopper, V. Falcão and J. Gibbons; "The Active Badge Location System.", Olivetti Research Ltd. (ORL), Cambridge, England, 1992.

[9] Cambridge University Computer Laboratori, "The Bat ultrasonic location system", http://www.cl.cam.ac.uk/Research/DTG/attarchive/bat/
[10] N.B. Priyantha, A. Chakraborty, and H. Balakrishnan, "The Cricket Location-Support System", Proceedings of the 6th Annual {ACM} International Conference on Mobile Computing and Networking (ACM MOBICOM), Boston, MA, August 2000.
[11] Ron Weinstein, "RFID: A Technical overview and its applications to enterprise.", IEEE IT Professional, Volume 7, Issue 3, pp. 27–33, May-June 2005.
[12] D. Hahnel, W. Burgard, D. Fox, K. Fishkin, M. Philipose, "Mapping and localization with RFID technology", Proceedings of the 2004 IEEE International Conference on Robotics & Automation, Volume 1, pp. 1015–1020 Vol.1, 2004.
[13] S.S. Manapure, H. Darabi, V. Patel, P. Banerjee, "A Comparative Study of Radio Frequency-Based Indoor Location Sensing Systems.", IEEE International Conference on Networking, Sensing and Control 2004, Volume 2, pp. 1265–1270 Vol.2, 2004.
[14] Heikki Laitinen (editor), Suvi Ahonen, Sofoklis Kyriazakos, Jaakko Lähteenmäki, Raffaele Menolascino, Seppo Parkkila, "Cellular location technology.", IST CELLO Project Deliverable, Document Id: CELLO-WP2-VTT-D03-007-Int, Nov. 2001.
[15] N. Bulusu, J. Heidemann, D. Estrin, "GPS-less low-cost outdoor localization for Very Small Devices.", IEEE Personal Communications, Volume 7, Issue 5, pp. 28–34, Oct. 2000.