Location-Assisted Handover for Multimode Mobile Terminals

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Abstract

Present day mobile networks and terminals are rapidly evolving. Wireless networks are evolving towards heterogeneous overlaying infrastructure, while the mobile terminals towards having multimode functionality. Traditional horizontal handover decision mechanisms that mainly depend on signal strength for decision making are unable to realize ubiquitous and seamless mobility across heterogeneous networks as well as true multimode functionality in mobile terminals. Use of location information in decision making would certainly enhance intra and inter technology handover mechanisms by supporting optimized handover management and enhanced terminal operation. As terminals evolve and adopt further wireless technologies for their interfaces, these issues become more important to the early concept and design of such terminals. This paper proposes and describes a novel multimode mobile terminal architecture suitable for realizing location-assisted handover.

1. Introduction

Location-aware applications and services are applications on the mobile terminal (MT) or in the network that make use of location/position information in some way to provide a particular service. Applications do this by combining the position information with some *context* information which lets them interpret and translate the location information into something that can be used in refining application content or making decisions.

Present day wireless communications networks and devices are experiencing a paradigm shift. Rapid emergence of diverse access technologies, e.g. WLAN, Bluetooth, 3GPP cellular networks (GSM, GPRS, UMTS), DVB-H (Digital Video Broadcasting-Handheld), etc would result in evolution of wireless networks towards heterogeneous all-IP infrastructure. In this heterogeneous overlaying infrastructure, traditional handover (HO) decision mechanisms that mainly depend on radio signal measurements (i.e. received signal strength, signal to noise ration, etc) for decision making are unable to realize ubiquitous and seamless mobility as well as true multimode functionality (simultaneous use of multiple interfaces) in MTs. Specially, in environments that have smaller network cells (hot spots) and high user mobility the conventional radio signal based HO decision methods could trigger unnecessary HOs.

Location-assisted handover (LAH) is the use of position information to aid and optimize HO and interface selection decisions within the multimode MT. LAH supports more intelligent HO services that would certainly enhance intra and inter technology handover and interface activation/deactivation mechanisms that would ensure optimized terminal operation. We have developed a novel multimode mobile terminal architecture in order to realize LAH for such terminals and defined the working principles of different functional modules.

The rest of the paper is organized as follows. Section 2 highlights the advantages of LAH. Section 3 illustrates the multimode mobile terminal architecture for LAH. Section 4 discusses possibilities of providing additional support like management and discovery of context information required for realizing LAH. Section 5 highlights an alternative approach for discovering location information using neighboring devices. Finally, section 6 concludes the paper.

2. Benefits of LAH

Benefits of LAH can be ascertained from the scenario illustrated in Figure 1, where the MT arrives at the intersection region of three different wireless networks. According to the decision module, which considers network capabilities only for decision making, the MT has three options – (i) move to network-B (1st preference) (ii) stay in network-A (2nd preference) (iii) move to network-C (3rd preference). If the MT considers user location and movement, network coverage, etc it should decide moving towards the coverage of the least preferred network (network-C). Because, if the MT decides to switch to network-B due to its direction of movement there must be another HO in a very short time, which would incur unwanted overhead. On the contrary, the MT may want to remain connected through network-A as long as possible. Then, for seamlessness it is also critical to initiate the HO process (either to network-B or network-C), or at least the initial time consuming phases like discovering the neighboring networks, address generation, etc, well before the time when the HO is mandatory (*proactive HO*) due to loss of connection with the current network. The *time window (T)*, as shown in Figure 1, represents the time instance when HO should be initiated in advance. T must not be long enough to initiate unnecessary HO and must not be short enough to create unwanted interruption due to unavailability of the current network for late HO initiation or because the HO has not yet finished.

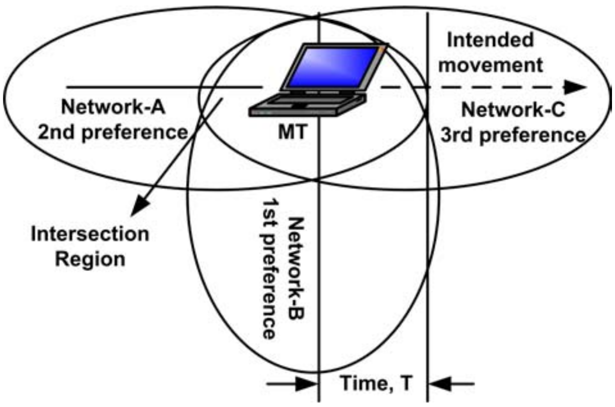

Figure 1. Critical HO scenario

Benefits of LAH can be summarized as follows:

2.1. Support optimized HO management

Firstly, the position and direction of movement of the MT can be used to determine that the MT is about to lose coverage of a particular network that is currently in use. This would allow the MT to predict the HO and prepare for it. Preparation for it could involve transferring existing sessions to another interface (if there is one available) or activating another interface in advance of losing coverage. It could also be used to eliminate hysteresis effects of the MT switching repeatedly between the same two base stations.

Secondly, knowledge of location can also be used to find out which other networks are available in the vicinity. Therefore, the MT could select the new base station in advance of the HO taking place. This would enable fast HO to take place.

Thirdly, from the network point of view, this enhanced MT behavior would also assist in optimization of the radio resources. It would additionally benefit *Quality of Service (QoS)* provisioning, as MTs that may have been previously operating in an area of poor signal strength, may now be in a better reception area, thus allowing a better QoS.

Finally, it is also possible to support HO (mobility) between different technologies, as the network is now capable of transmitting the position of a MT to another network technology overlapping the same geographical area.

2.2. Support enhanced terminal operation

Firstly, information about location could be used to provide extra input to the interface selection decision. For example, if it can be known from the location information that the MT is not far from the edge of network coverage, then the interface about to lose coverage may be discounted from the interfaces available because there is no point starting a new session over an interface that is about to disappear.

Secondly, information about location could also be used to indicate that a new interface will be available in the near future, so that session commencement could be delayed pending a better interface selection decision.

Thirdly, location information could be used to indicate to the MT that it may be worth activating a particular interface because it is known that there is, for example, WLAN coverage at the given location. This can avoid the need for the MT to expend processing and battery power scanning for networks.

Finally, it may also be beneficial to know that a particular access technology is definitely not available – thereby saving power that might otherwise be spent scanning for it.

3. Multimode terminal architecture for LAH

The architecture of the multimode terminal supporting LAH is illustrated in Figure 2. The problem of determining and making use of location information to assist in HO and interface selection decisions can be subdivided into two areas, firstly, position determination and secondly, interpretation and use of location information. Consequently, our architecture consists of two major parts, namely, the *Positioning Functions*, and the *LAH Functions*. The former determines the position of the MT and the latter interprets and uses the location information for decision making and HO.

3.1. Positioning functions

The Positioning Functions can be further split into three parts namely, the *Positioning Functionality within the Interface Technology*, the *Position Determination Function*, and the *Higher Layer Refinement Functions*.

3.1.1. Positioning functionality within the interface technology. There is a large number of technology specific techniques for determining position of the MT:

- "Cell" Identifier
- "Cell" Broadcast
- Angle of Arrival (AOA)
- Received Signal Strength Indication (RSSI)
- (Uplink) Time of Arrival (TOA)
- (Uplink) Time Difference of Arrival (TDOA)
- Downlink Observed Time Difference (DOTD)
- Return Time of Flight (RTOF)
- Location Pattern Matching (LPM)
- Global Positioning System (GPS) including Differential GPS (DGPS) and Assisted GPS (A-GPS)

Some of the above techniques are already available on existing terminals and with existing networks ("Cell" Identifier, "Cell" Broadcast for cell ID, TOA, TDOA, DOTD, and GPS) while others would require changes to the terminal, or the network, or both (AOA, RSSI, RTOF, and LPM). No single technique is superior in terms of accuracy, response delay, or coverage. In particular, many of the techniques (AOA, TOA, TDOA, DOTD, RTOF, and GPS) are affected by *multipath* propagation of radio signal and most accurate when there is a *line of sight* between the infrastructure nodes and the terminal in question, which is not always possible. Given that there is no single all encompassing technique, there is potential for integration of different techniques, particularly, on a multimode terminal. Types of location information determined by the above techniques can be categorized as, firstly, identity of base station or access point, secondly, postcode, and finally, absolute position expressed in two or three dimensional coordinates (latitude, longitude and/or altitude). A summary of the location determination techniques is shown in Table 1.

Location information needs to be passed between functions within the terminal and also, in some cases, between the terminal and the network. It is important that the sender and receiver of the location information have the same understanding of the format of the information that has been sent. The following standardization bodies are working on this issue:

- The Geographic Location/Privacy (Geopriv) working group of the IETF [1], [2], [3], [4], [5]
- IEEE 802.11K [1], [6]
- The OMA Location Working Group (LOC) continuing the work of the Location Interoperability Forum (LIF) [7], [8]

Table 1. Summary of location determination techniques

	Cell ID	Cell b'cast	AOA	RSSI	TOA/ TDOA	DOTD	RTOF	LPM	GPS
Changes required in MT/network	Neither	Both	Network	Network	Network	Both	Both	Both	MT
Network/MT based	MT	MT	Network	Network	Network	MT or Network	Network	Network	MT
Currently in standards	GSM, UMTS, WLAN	-	-	-	GSM, UMTS	UMTS	-	-	-
Line of sight required	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
No. of infrastructure nodes visible	1	1	≥ 3	≥ 4	≥ 4	≥ 4	≥ 4	1	≥ 4
Suitability for urban areas	Good	Good	Poor	Poor	Poor	Poor	Poor	Good	OK
Calibration requirements	None	None	Antenna array	None	Time in network & MT	Time in network	None	Coverage map	Time in Satellites (done)

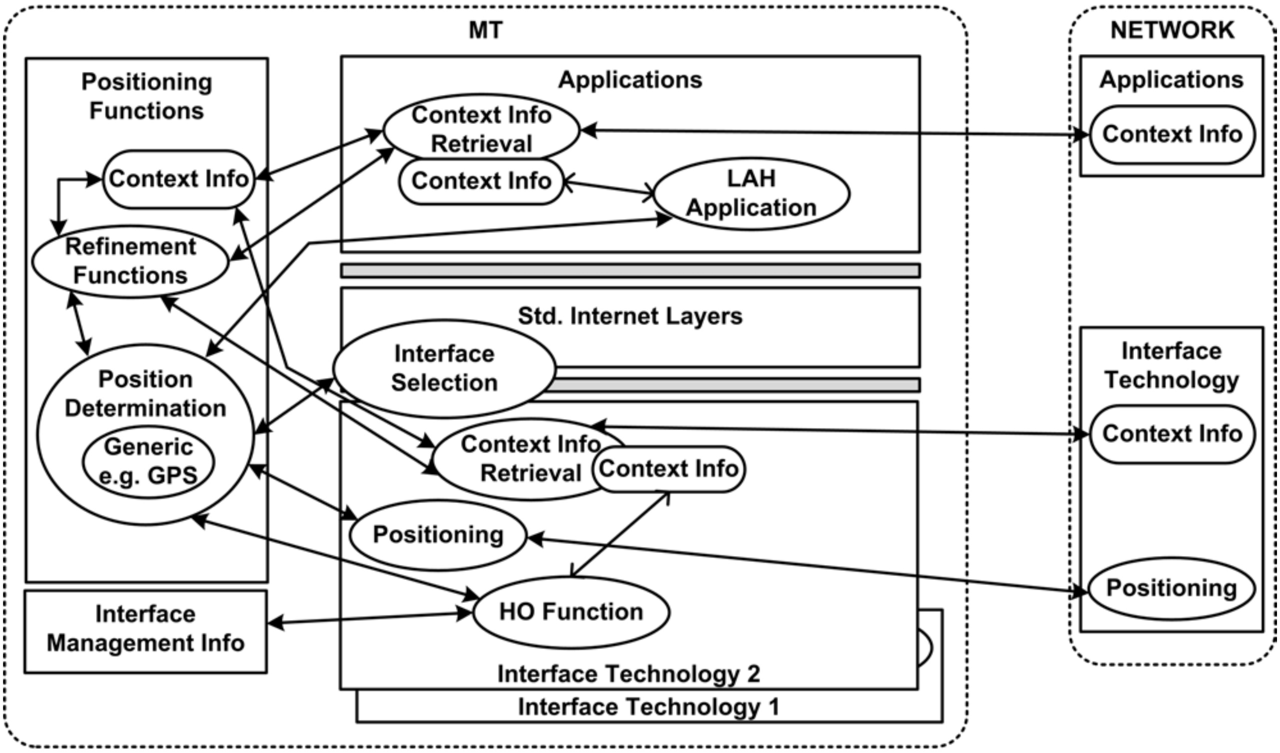

Figure 2. Multimode mobile terminal architecture for LAH

3.1.2. Position determination function. This function coordinates/makes use of information received from the different interface technologies, possibly combining information from different interfaces to enhance accuracy, makes use of interface technology independent positioning techniques e.g. GPS, and finally, provides the position information to the LAH Functions on query/request. The coordination function for the Position Determination Function provides an interface to the applications and controls which technique is used to obtain location information and whether or not it needs further refinement to be information of the right type. The coordination algorithm is illustrated in Figure 3.

3.1.3. Higher layer refinement functions. These functions, named as such because they can be application level functions, map between different location information types and formats (possibly using context information from the network). The Position Determination Function uses these functions in order to provide the position information in requested formats. The main mechanism used to implement these functions is some form of database. The accuracy of the information returned will depend on the measured data, database resolution, accuracy of the location algorithm and number of measurements. The major effort lies in the creation and maintenance of the database. There are three possibilities for doing this:

Firstly, the database could be built up and stored on the terminal. The advantage is there is no extra load on the air interface or time delay of contacting the network. However, the complexity required on the terminal is non-trivial and many terminals will all be building exact copies of the same database.

Secondly, the database could be provided by the network and the look-ups performed when necessary. Information formats such as those discussed earlier could be used to transfer information across the air interface. However, in this case, the load on the air interface may be increased and the time taken to perform the look-up may vary depending on the network.

Finally, the above methods could be combined by the terminal maintaining a small cache of regularly visited areas. If the current location is not in the cache then a look-up from the network will need to be done. If the terminal is taken repeatedly to the same area, then the majority of the time the cache will be sufficient and there will not be extra load or time delay.

3.2. LAH functions

The LAH support on the multimode terminal occurs at both the application layer and within a particular interface technology. The Positioning Functions support two separate LAH Functions:

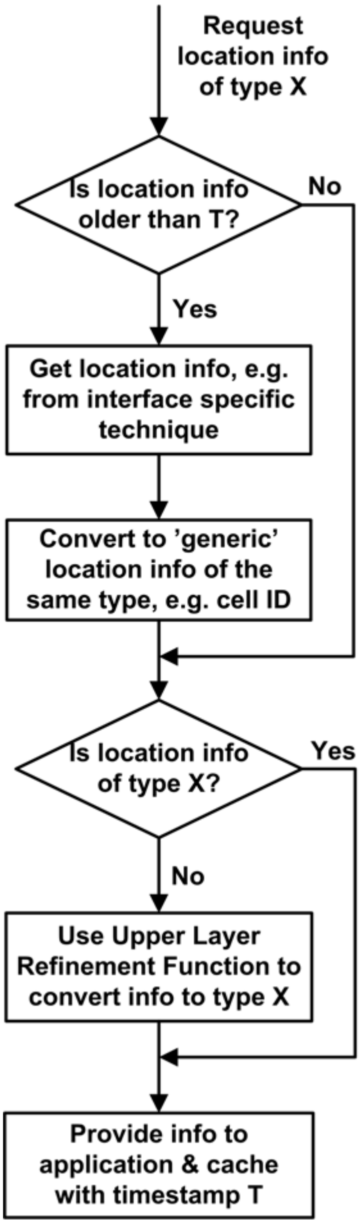

Figure 3. The Positioning Function Coordination Algorithm

Firstly, the *LAH Application* which is responsible for processing positioning information in order to determine when an interface should be activated or deactivated (basically supporting inter-technology HOs).

Secondly, the *HO Function* within the Interface Technology itself, which can use location information to augment intra-technology HO decisions.

The LAH Functions interact with the Positioning Functions via an *Application Programming Interface (API)* that allows them to request location information in a certain format with a particular accuracy from the positioning functions. A basic API would include the following basic functionalities:

Query: This functionality is used by applications to determine what positioning information is available in abstract terms, i.e. what "type" of information is available, what the accuracy is etc.

Notify: This functionality is used by the positioning functions to indicate to applications that different positioning information has become available e.g. if a different network support finer granularity of information.

Request: This functionality is used by applications to request position information. The request should include the required format and accuracy needed by the application, and whether the position information is needed now, periodically, or when some event happens etc.

Report: This functionality is used by the Positioning Function to report the positioning information to the application, including a timestamp of when the positioning information was determined.

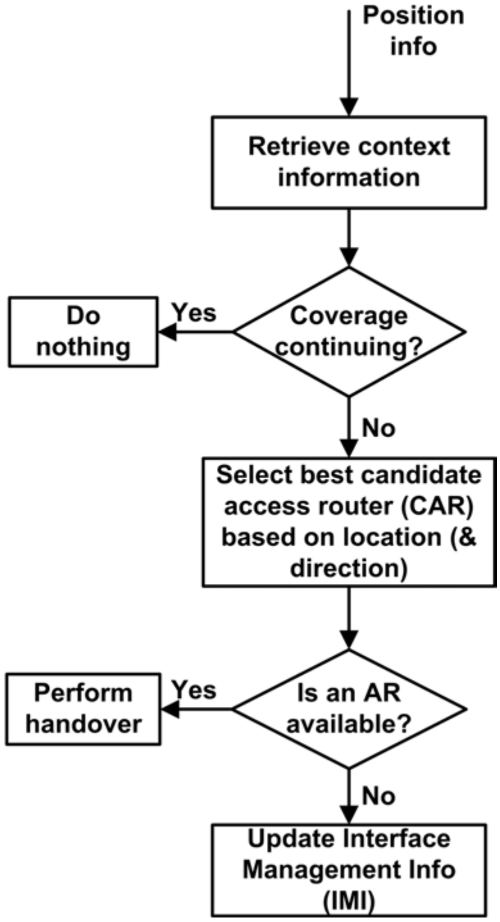

Figure 4. Interpretation algorithm for intra-technology HO

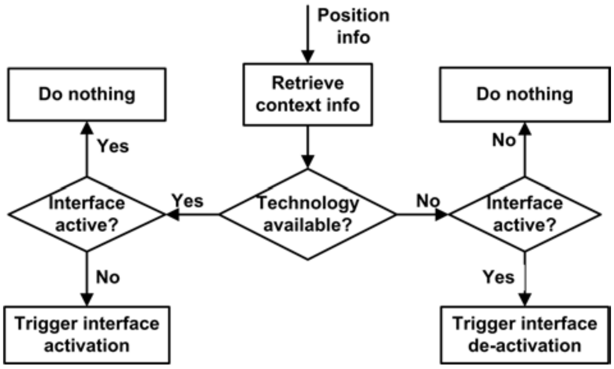

Figure 5. Interface activation or deactivation algorithm

Within the LAH Application and the interface technology specific HO Function, some processing of the location information and the context information must be performed on the MT using *Interpretation Algorithms* in order to determine what action to take next. Figure 4 and 5 illustrate the algorithms for intra-technology HO and the more general multimode interface activation/deactivation, respectively. The processing and context information required is different in these two cases. For the former, the base station identity or the co-ordinates can be combined with a number of different pieces of context information to support enhanced handover decisions. These include a "map" of the local network to work out where in the network footprint the device is currently located, a "map" of the base stations, and information associated with the location information indicating whether or not network coverage was available at this position when the MT was last here. For the latter, the context information used for interpretation can consist of a list of technologies available at a particular location, which can be learned by the MT over time, or potentially retrieved from the network.

3.3. Use case

An example use of a specific location technique (in this case cell ID) within the above architecture is shown in Figure 6. The information flow is as follows (the application has requested two dimensional coordinates; the positioning technique in use is cell ID):

1. The new cell ID is received at the link layer. The exact format of the cell ID received is specific to the interface technology in use.
2. The position determination function will receive it from the interface specific positioning function.
3. The interface specific cell ID is converted to a generic format of cell ID (interface technology specific information is always converted to generic information format of the appropriate type).
4. The cell ID is given to the upper layer refinement function.
5. The refinement function uses information either from the terminal's database or retrieved from the network to convert the cell ID into a two dimensional coordinate.
6. The two dimensional coordinates are passed back to the position determination function.
7. The two dimensional coordinates are given to the application requesting the information, for interpretation.

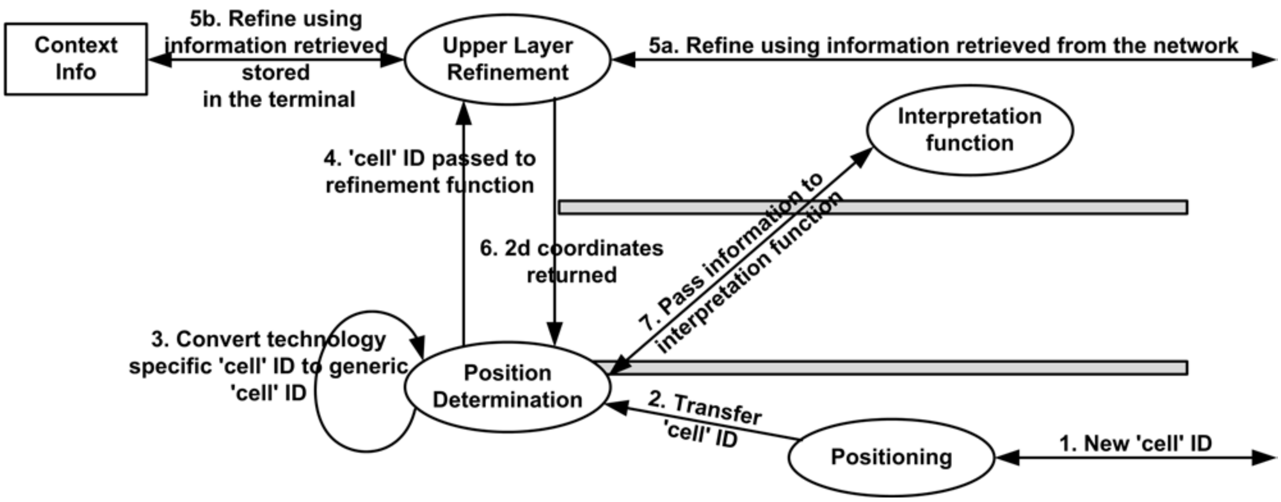

Figure 6. Use case for location information

4. Management and discovery of context information for LAH

There are two main approaches to interpreting location information that can be adopted by the MT. Firstly, use locally stored information to interpret the location information, and secondly, each decision, or some useful grouping of a set of decisions, query the network dynamically for associated context.

4.1. Local context information storage

Firstly, the information can be installed on the MT, by the user or the operator, and periodically updated via downloads either over the air, or via a PC connection e.g. using xDSL and USB.

Secondly, the information can be pushed to the MT by the network, and may be offered to the user by the local access network operator, the user's service provider, or even by a third party provider. This would be similar to SIM card updates available in current cellular networks.

Finally, the MT can learn about particular locations, and store context information in an on-going way as the handset moves around the network.

The advantage of caching the information locally is that the information is always available regardless of the capabilities of the network. It also supports faster local decision making as there is no delay whilst the information is retrieved from the network.

However, there is an additional requirement for storage space locally within the MT, and there is a question about the lifetime of the information. In order to keep this information up to date, the information should timeout and be updated periodically to keep up with changes to network topology, coverage etc.

4.2. Dynamic context information retrieval

Context information may be held in the network and queried by the MT as and when required. This information could be retrieved from the local access network, the operator home network, or even a third party network and either downloaded or queried.

A benefit of this method, compared to the local context storage is that it allows more information to be used when interpreting location information as it does not have local storage constraints. The main disadvantage is that this information may become unavailable as the user moves around the network.

Protocols for retrieving this context information could include:

Firstly, in cases where the network calculates position and delivers the information to the MT, the context information could be piggybacked into the same message exchange. A standard way to deliver location information to an MT is under development by OMA LIF [7], and could be extended to perform context information delivery as well.

Secondly, a suite of application layer solutions could be developed to retrieve this information, for example, by allowing downloads of files over existing protocols such as HTTP, FTP etc. Alternatively, existing protocols could be used for this purpose, such as the *Lightweight Directory Access Protocol (LDAP)* [9].

The location of the context information servers could be pre-configured on the device, or discovered dynamically via protocols such as *Service Location Protocol (SLP)* [10].

5. Discovering location information from neighboring devices

In this alternative approach, the basic idea is that for devices that do not have native support for positioning functionality it would be useful if they could access positioning information of neighboring devices to work out where they are. For example, a car driver's PDA could access location information that has been determined by the car and query for local restaurants etc. The idea can be summarized as follows:

We assume we have a device (*dev1*) that wishes to know where it is, but has no positioning functions directly available to it. There is a device (*dev2*) nearby that does know its own location. *dev1* discovers and probes local devices to query whether any of them offer positioning functionality/location information. *dev2* responds to the query. *dev1* and *dev2* potentially exchange a number of messages allowing dev1 to determine location and get this information into a suitable format. An example of how we could implement this would be using Bluetooth with a new inquiry access code indicating that *dev2* is a "Positioner". The range of Bluetooth automatically implies that *dev1* and *dev2* must be near each other.

6. Conclusions

In this paper, multimode terminal architecture for supporting LAH is proposed and working principles of different functional modules have been defined. Furthermore, possible approaches for management and discovery of context information for LAH using existing or upcoming standards, and an alternative approach to discover location information using existing location based services have also been discussed. This would surely give the platform needed for future implementation of LAH enabled multimode terminals.

The LAH bears immense potential and utmost importance in days to come especially for heterogeneous networks and multimode MT. The LAH functionality consists of intra-technology HO and interface activation/de-activation functionality. For the former, further investigation is needed to determine whether the benefits provided by implementing this functionality outweigh the additional complexity required within the MT. The latter is one that is particular to multimode devices, and can play an important role in preserving battery life and supporting seamless transfer of sessions between interfaces. The additional complexity required on the MT to support this is minimal, but has a dependency on a number of functional areas like determination of location and location information format, and availability of context information.

In future research, we intend to investigate the LAH issue further in order to refine our architecture. Later, we intend to implement the architecture as simulation software.

7. References

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