SIP for Wireless Positioning: System and Architecture

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***Abstract*— The recent boom in wireless communications has led to a wide range of new applications. Wireless positioning is an emerging technology which can provide accurate locations for indoor environments when satellite based positioning systems are not available. In this paper, a Session Initiation Protocol (SIP) based system architecture for wireless positioning is described and an overview of how this can be used in overall system architecture has been provided. The proposed system architecture has shown that SIP is competent as a network signaling protocol for wireless positioning.**

I. Introduction

Current positioning and navigation systems are predominantly satellite based, i.e. Global Positioning System (GPS) and the European Galileo system. A main drawback of these systems is the poor indoor performance. The recent boom in wireless communications has provided a huge population of mobile devices with a wide range of new applications. Naturally, this huge population of mobile devices provides a powerful platform for positioning which can enhance the indoor performance when satellite based positioning systems is not available. The mobile location service and personal navigation represent a huge potential and challenge for business players in the mobile service arena [1]. The potential advantages open a huge market to develop wireless positioning and navigation systems which can operate in both indoor and outdoor environments with high availability and accuracy. Meanwhile, the booming of the Internet services and many wireless mobile technologies have been developed to satisfy the Quality of Service (QoS) requirement of end users for numerous multimedia applications. The state-of-the-art 3G UMTS mobile technology, WLAN, IEEE 802.1x, WPAN (including Bluetooth), etc., have been extensively developed to provide high speed wireless Internet access anywhere and anytime.

There are several approaches for the network signaling protocol in a mobile wireless positioning system. At the physical layer, the ranging and other related signaling messages are exchanged between peer-to-peer mobile devices in the network, such as Bluetooth network, WLAN, etc. A logical solution is to use existing and deployed technology at the physical layer to recover ranging information and have this information passed up to the application layer for positioning. This would entail the ranging information being transferred between devices for recovery of location from ranges between particular devices in the network. A protocol to define the passage of this information at the application layer is necessary and would most conveniently use an existing application layer messaging protocol.

In this paper, we focus on the system design for wireless positioning. A SIP signaling protocol for wireless positioning technology is proposed. The paper is organized as follows: In Section 2, we specify the requirements for wireless positioning systems, Section 3 contains the proposal for both the system architecture and the signaling protocol, and finally, conclusions are provided in Section 4.

II. System Requirements for Wireless Positioning

Accurate wireless indoor positioning is a new research field with many new specifications and open issues. Recently, a large number of wireless localization systems has been proposed and evaluated [2, 3, 4, 5]. From a system point of view, it should be operable seamlessly over many wireless technologies, such as UMTS, WLAN, and Bluetooth. It should be delay bounded to be able to reflect the up-to-date knowledge of the location. Inevitably, it needs to tolerate some degree to interference. Therefore, the following parameters must be specified:

- **Latency:** The time between a request for the position of a mobile device and the response to the query. At the time when a position is determined, its location maybe accurate and up-to-date. However, if the time response is too long, the location of the device may have changed significantly.
- **Update rate:** The update rate is the frequency of position calculation and distribution. It can be done periodically or on-demand, and thus varies among applications, e.g. tracking requires continuous calculation and update.
- **Synchronicity and timing:** All ranging measurements must be synchronous over the system to avoid errors in the position estimation, e.g. when the node is moving.
- **Accuracy and confidence level:** These are key requirements of a wireless positioning system, and relate to the outcome of a geodetic network positioning strategy [6].

1-4244-0368-5/06/$20.00 © 2006 IEEE

III. SIP FOR WIRELESS POSITIONING

A. *Why SIP?*

The Session Initiation Protocol (SIP) is a recent development of session management with IETF RFC 3261 proposed standard appearing in 2002 [7]. It is a text based HTTP like application control protocol that can establish, modify and terminate multimedia sessions such as VoIP conferences. The basic architecture of SIP is client-server with the main entities including the user agents, the SIP gateway, the proxy server, the location server, the redirect and the registrar servers. Although originally proposed for VoIP, SIP has quickly evolved into Wireless IP, such as UMTS, WLAN. Since SIP is the application control layer signaling protocol, it gives the lower layer independent capability to the wireless positioning system. It thus enables seamless cross-network operations (e.g. Bluetooth, UMTS, WLAN, etc.) and simplifies message signaling protocol as well as scalability. Characteristics of SIP for wireless positioning can be summed up as follows:

Simplicity and timing: SIP is very lightweight, and can run on devices with limited processing capabilities. By using time-related fields in the SIP header, such as time tag, expire, etc., the specified requirements for wireless positioning, e.g. the latency, accuracy or confidence level, can be achieved.

Generic: SIP separates the signaling of sessions from the description of the sessions. SIP can be used to initiate and control completely new types of session.

Modularity and extensibility: SIP is designed to be extensible allowing implementations with different features to be compatible.

Integration: SIP can integrate with other IP protocols, which enables for wireless positioning systems to have cross-network operations.

Scalability and robustness: As SIP is an application layer protocol and independent from lower layers, it can operate in small networks (piconet), larger networks (scatternet, LAN, PAN) or large geo-scale networks (MAN or worldwide scale).

Regarding the specified system requirements of wireless positioning [8], SIP is competent as a network signaling protocol for wireless positioning.

B. *System design*

The proposed SIP architecture for Wireless Positioning is based on SIP Mobility Management for Wireless Communication. Fig. 1 shows a basic SIP system architecture for Wireless Positioning, which consists of SIP gateway, proxy server, redirect server, registrar server and location server. The information of the SIP user, device's ID, access ports, and other ranging information (which is obtained from ranging process to nearby devices) and related time stamp are conveyed to the registrar server by using the REGISTER method. This information is to be processed by the positioning software on the location server. Including known positions of nearby anchor nodes, it is possible for the positioning application to identify the coordinate position and accuracy of each registered device. The device's position and other related information such as quality indicators are then stored on the location database of the location server.

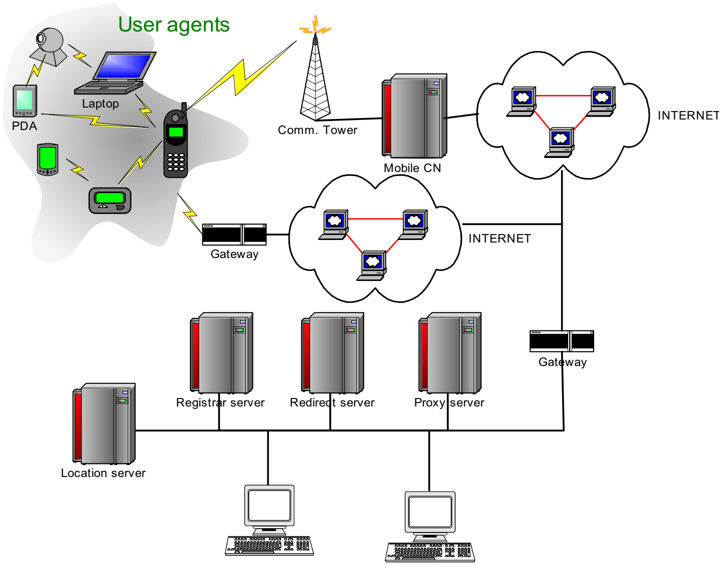

Fig. 1. SIP system architecture for Wireless Positioning.

The registration temporarily binds a user's Uniform Resource Identifier (URI) with a Contact URI of a particular device. Such a contact URI field in the SIP header should also contain other ranging information. The user can move between the service providers and use multiple layer registrations. The contact URI field can contain timing related information described in the specification requirements, such as an expire parameter, which indicates how long the contact information is valid. In order to establish a common time reference and identify the latency and validity of information messages, a time tag is also included in the header fields.

When the SIP user agent would like to query location information or other information of a user agent, it could use the OPTIONS method for query. The OPTIONS request is generated by user agent and when the server receives the query with callee's user agent ID, such as SIP URI, time valid, it will look at the location database on the location server to find the position information of the callee. Otherwise it will forward the request to the callee. The server or callee sends back to the caller the response message in the same way as it would do to an INVITE request. The success 2xx class response (e.g. 200 OK message) contains the position information of the callee, including time tag of the last position update, SIP address, device ID, position coordinate, and accuracy level.

C. *Protocol Design*

As SIP is a text based HTML like application control protocol, it is not as complicated for compiling and processing as other lower layer protocols. There are several methods to embed information including device location information on SIP messages. However from the point of view that Wireless Positioning is an extension of Wireless Mobility Management, the SIP protocol for Wireless Positioning could be based on current SIP messages for Mobility Management with some modifications. Two basic SIP request messages proposed for Wireless Positioning are: REGISTER and OPTIONS. Including those two requests, the SIP response messages still follow IETF RFC SIP definitions with some modifications.

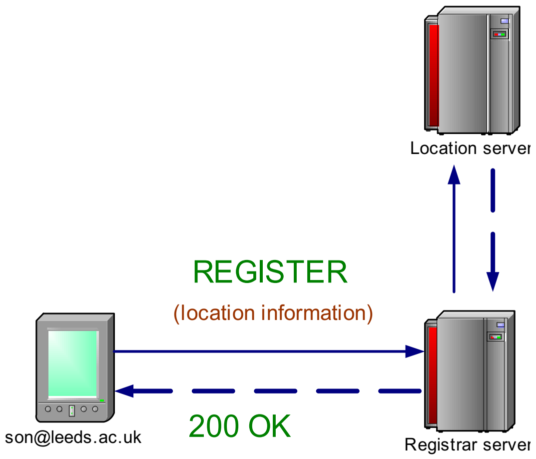

Fig. 2. An example of SIP registration session for wireless positioning.

The modified 200 OK response is used to carry location information. Fig. 2 gives a simple example of the SIP position registration process. When a mobile agent would like to register its position relative to nearby devices (i.e. its ranges to nearby devices), the mobile user agent sends a REGISTER request, which contains its position information (e.g. its SIP address and device ID, device IDs, ranges and RSSIs of nearby devices) to its host REGISTRAR server. This REGISTER request is sent either periodically or when the mobile device detects a change in position or adjacent ranges. The contact header field is used for carrying position information, the header expire field indicates the server how long the provided information is valid. After the time is expired, the mobile user agent sends a new registration request. The REGISTER header field contains date and time stamp to inform the server when the request was generated. The following example of a SIP REGISTER message for wireless positioning is generated by the SIP user and sends to the registrar server. It contains SIP and device's IDs, timing, ranges and confidence levels to nearby devices and their IDs:

```
REGISTER sip: registrar.leeds.ac.uk
SIP/2.0
Via:SIP/2.0/UDP 101.102.103.104:5060;
branch=k3hGts322
Max-Forwards:70
To: sip: son@leeds.ac.uk
From: <sip:son@leeds.ac.uk>; tag=32345
Call-ID: 673428452362.4.3.1
CSeq: 1 REGISTER
Date: Tue, 8 Mar 2005 23:29:15 GMT
Contact:sip:son@leeds.ac.uk:5060;trans
port=udp;user=ip;ttl=12;maddr=176.23.1
29.211@Subject=Position
ID=15A7H82334E3 ID_1=25B45A8334D1
R_1=5.23 RSSI_1=6 ID_2=2133A4D234F1
R_2=7.20 RSSI_2=2
Expires: 30
Timestamp:af2445b7a6
Content-Length: 0
```

The registrar server receives the registration message, then stores the user agent's location information to the location database. The coordinates of the user agent are determined based on the device IDs and ranging information of nearby devices by the position application on the location server. The REGISTER request may be forwarded until it reaches the authoritative registrar server for the specified domain. The server then sends a response back to the user agent. If the receiving is successful, a 2xx response is sent. 3xx is sent for redirection, 4xx and 5xx for client and server errors. In the Fig. 2, the server sends 200 OK response to the user agent to confirm its successful location registration, and the 200 OK message is as follows:

```
SIP/2.0 OK
Via:SIP/2.0/UDP101.102.103.104:5060;
branch=k3hGts322; received:
192.02.27.11
Max-Forwards:70
To: sip: son@leeds.ac.uk
From: <sip:son@leeds.ac.uk>; tag=32345
Call-ID: 673428452362.4.3.1
CSeq: 1 REGISTER
Date: Tue, 8 Mar 2005 23:29:12 GMT
Contact:sip:son@leeds.ac.uk:5060;trans
port=udp;user=ip;ttl=12;maddr=176.23.1
29.211@Subject=Position
ID=15A7H82334E3 ID_1=25B45A8334D1
R_1=5.23 RSSI_1=6 ID_2=2133A4D234F1
R_2=7.20 RSSI_2=2
Content-Length: 0
```

When a SIP user agent would like to get information about the location or the capabilities of a SIP user agent, it uses the OPTIONS method. Fig. 3 shows an example of OPTIONS request. The user agent sends an OPTIONS request about location information of a SIP user agent The request should contain Call-ID, TO, FROM, CSEQ, VIA, MAX-FORWARD, and in CONTENT FIELD, it could contain LOCATION OPTION and TIME VALID, which contains the specific time request of the callee's position. If the server finds the callee's address and valid coordinate position in its location database, it will process the SEND BACK RESPONSE message, otherwise it would forward the REQUEST message to the callee. An example of OPTIONS request could read as:

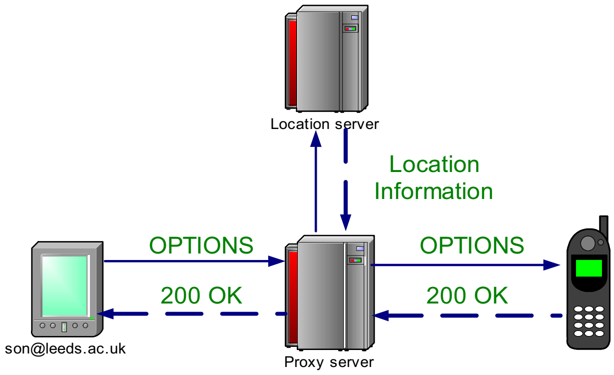

Fig. 3. An example for SIP session for position notification.

```
OPTIONS sip: son@leeds.ac.uk SIP/2.0
Via:SIP/2.0/UDP 101.102.103.104:5060;
branch=k3hGts322
Max-Forwards:70
To: sip: son@leeds.ac.uk
From:<sip:tony@leeds.ac.uk>; tag=32345
Call-ID: 546
428434562.1.2.6
CSeq: 1 OPTION
Date: Tue, 8 Mar 2005 23:29:15 GMT
Contact: sip: tony@leeds.ac.uk
@Subject=Position Date_=080382005
Time_=23:29:12 GMT
Expires: 30
Timestamp:af2445b7a6
Content-Length: 0
```

When the server receives this request, it searches the location database for the user address with valid date and time, and sends back a response to the caller, otherwise it forwards the request to the callee. The request message is forwarded via several intermediate servers until it reaches the destination server. If the callee's information is found, it will send back the 200 OK response message to the caller with its location information on location database, otherwise an UNFOUND message would be responded. An example of the 200 OK response message containing the position and other related information is as follows

```
SIP/2.0 OK
Via:SIP/2.0/UDP 101.102.103.104:5060;
branch=k3hGts322; received:
192.02.27.11
Max-Forwards:70
To: sip: son@leeds.ac.uk
From:<sip:tony@leeds.ac.uk>; tag=32345
Call-ID: 546428434562.1.2.6
CSeq: 1 OPTION
Date: Tue, 8 Mar 2005 23:29:15 GMT
Contact:sip:son@leeds.ac.uk:5060;trans
port=udp;user=ip;ttl=12;maddr=176.23.1
29.211@Subject=Position
Date_=080382005 Time_=23:29:12 GMT
ID=15A7H82334E3 X_=6 Y_=3 Z_=5
Content-Length: 0
```

The REGISTER and OPTIONS methods can be carried out in pre-call or on-flying (e.g. the user is in media exchange with other users) or when the SIP mobile agent is on roaming. A simple way for registering a mobile agent is followed by a double registration process one to a local server and the other to the home server. When switching to a new network with a new IP address, the registration could cause some negligible interruptions. If this is not the case, some packets can be lost as the media catches up with the signaling, and some slight interruptions could occur. Thus a re-INVITE request should be done

IV. CONCLUSIONS

A SIP based system architecture for wireless positioning has been designed and a high level system architecture has been provided. However, not all issues have been considered in this paper. Further work will address the following questions: (1) How the latency of data distribution across the network will impact the tracking capability of devices (this will be especially serious when a mobile node is moving in/out of a network which a handoff will be made); (2) An assessment of the overall network load in order to determine whether the positioning traffic can be implemented as background traffic to an existing network or whether a dedicated network is required; (3) Problems related to the ad hoc model will need to be considered, such as the problem of routing and switching packets in the multi-hop network.

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