Design of Mobile Group Communication System in Ubiquitous Communication Network

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***Abstract*— The advent of ubiquitous IP networks enables users to freely move and continue network services anytime, anywhere by means of mobile handheld devices. This paper exploits network ubiquity and advanced device capability to develop a novel mobile group communication system. Our work presents the design and implementation of a proof-of concept software system. This system architecture consists of four components: central tracking, handheld tracking, handheld messaging and Web-based administration subsystems. Their functional integration thus fulfills both location tracking and mobile messaging services in support of mobile group communication. After prototype and demonstration, the proposed system is able to offer a variety of novel location-aware and text/voice communication scenarios to mobile social communities in ubiquitous IP network environments.**

***Keywords*— mobile group communication, mobile messaging, location tracking, ubiquitous service.**

I. INTRODUCTION

The convergence of wired, wireless and mobile network systems brings out a ubiquitous network environment [1]. Modern handheld devices (MHDs), such as mobile phone, personal digital assistant, mobile Interne device and ultra mobile PC, now feature multiple networking interfaces – for example, the sort of mobile phones that have GSM, 3G, 3.5G, Wi-Fi, and Bluetooth. Users with MHDs, a.k.a. mobile users, thus have global network connectivity to attach and move in different networks simultaneously, and higher data transmission capacities to access Internet files and media contents, that is, wireless Internet [2][3].

Fig. 1 illustrates a ubiquitous IP network environment. Mobile users now experience Internet and Web services anytime and anywhere in a way as much like as the accustomed way they operate on desktops. Remarkably, many MHDs are also featured with localization modules, such as GPS, AGPS and Wi-Fi, and associated with navigation engines together [4][5]. Not only ordinary Internet services, but also MHDs are able to operate mobile multimedia [6] and location-based information services [7][8] that are special in mobile contexts, relatively, not in traditional Internet domain. Therefore, the progress of network convergence and ubiquity offers service developers and users a vigorous playground of introducing new and potential mobile applications and services [9-14][21][22]. It is noteworthy that despite heterogeneity and interoperability across underlying network systems, standard TCP/IP and HTTP protocols indeed serve as a uniform communication platform on top of which application-level network service design and deployment can be carried out independently.

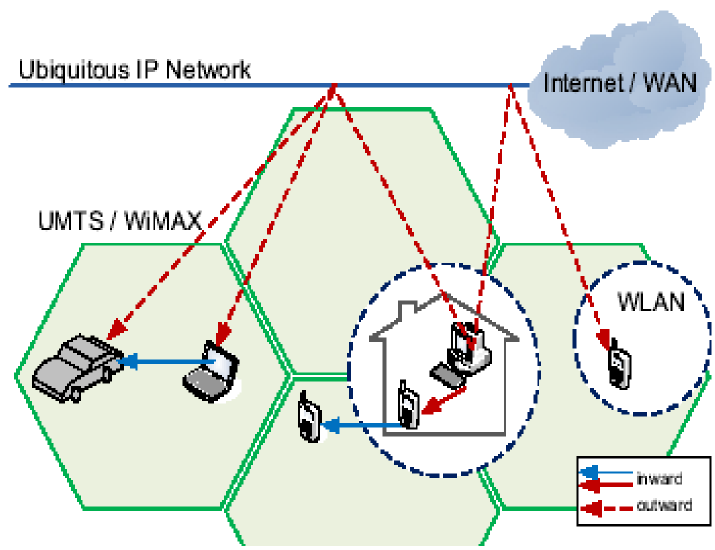

Figure 1.A Ubiquitous IP network environment

The work in this paper considers common features of many off-the-shelf MHDs' capabilities, including multiple network interfaces (GSM/3G/Wi-Fi), localization (GPS/AGPS) and map navigation, open service platform and development kits, application customization and deployment. From users' prospect, our work plans an interesting blueprint of group communication services in mobile social communities. Ideally, mobile users in a group are able to communicate with each other, regardless of their network locations and movements, in ubiquitous IP network environments.

For scenario realization, we design a mobile group communication software framework. This design consists of four functional mechanisms: central tracking, handheld tracking, handheld messaging and Web-based administration. Whereon, we further develop the location tracking and mobile messaging services, that are jointly used to perform the mobile group communication as planned. To achieve a proof of concept, we develop the proposed system architecture and applications on some non-proprietary open service platform [15]. The prototype can be deployed on target mobile phones and thus run across current UMTS/IMS and Wi-Fi networks. The demonstration results present several interesting use cases that get higher user experience.

The rest of this article is organized as follows. Section II introduces a scenario of mobile group communication. Section III designs the system architecture, subsystem and functional components, and interactive procedures. Section IV presents the prototype and demonstration. Concluding remarks and further work are given in Section V.

II. MOTIVATION AND SCENARIO DESIGN

Let's review a common travel experience: several peers appoint to visit a scenic spot, and they move from different places. Suppose that only a peer knows the precise location of the scenic spot. This peer has to call other peers one by one to tell them how to go there. Even though repetitive calls are made, someone always loses his/her way. Such a situation may become better if these peers would have modern MHDs or navigation devices. Peers can use MHDs to access on-line map directory, like Google map, or lookup stationary maps on navigation devices. In addition to vocal instructions by phone calls, peers can resort to digital maps to find the routes to the destination. However, a peer has no idea about other peers' locations and movements. If a peer is moving on a wrong way, no one can alert him/her immediately. In contrast, if peers saw that peer's position on their digital maps, they could instantly inform him/her of any warning events, which they would avoid many undesirable affairs in a collaborative manner.

Note that though a GPS navigation device can offer stationary map and routing information, its function is dedicated without support of network connectivity and communication. Comparatively, our work attempts to exploit localization, data communication, and map functionalities available on MHDs to enable peer locating and tracking, and messaging services among mobile peers. In practice, this sort of scenario is appealing in mobile and automobile information systems, but is not a real-life case in consumer devices as yet. We hence address a mobile group communication service to this end in this article.

Fig. 2 instantiates the blueprint and user scenarios we deliberate in ubiquitous IP network environments. Assume that a number of mobile peers form a mobile group in compliance with their social relationship. Every mobile peer is free to move to any place where a new peer is assigned a binding network address that can be reached by other peers over IP networks. From the aspects of location tracking and mobile messaging services, we deliberate that a mobile group communication system must support at least a set of featured functions below. Section III will further detail these functions.

- Dynamic group creation and participation
- Group membership configuration
- Support of vocal and text messages
- Support of online and offline messages
- Support of flexible message delivery modes
- Support of message encryption/decryption
- Resiliency against peer roaming and disconnection
- Authentication and verification
- Privacy-aware location protection
- Friendly and touch GUI
- Location tracking and historic log
- Remote operation, administration & management (OA&M)

Therefore, the design of the proposed mobile group communication system involves multifold technologies, such as mobile data management, message exchange protocol, secure access and control, remote administration, database maintenance, and flexible user interface, thereby providing an elaborate software architecture.

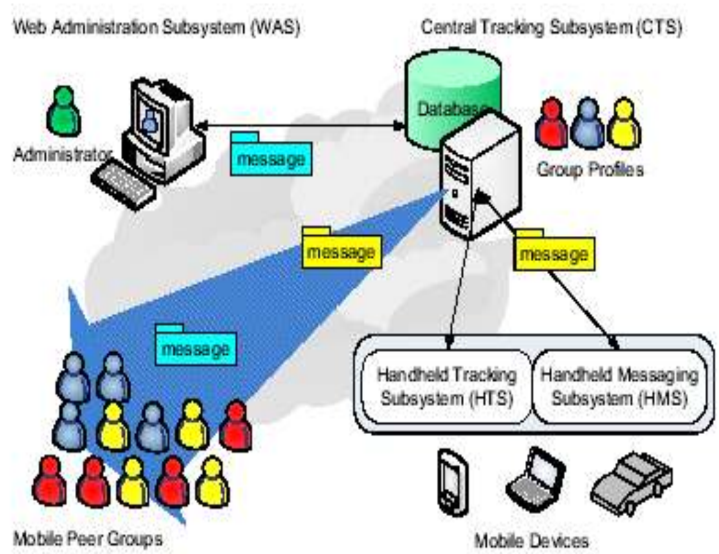

Figure 2. An illustrative scenario of mobile group communication

III. SYSTEM ARCHITECTURE

This section designs the system architecture. Section III.A firstly abstracts the system design and inclusive subsystems. Sections III.B-E specify respective subsystems, functional components, and usages. Section III.F describes major interactive processes among subsystems.

A. System Design Abstraction

The developed system architecture includes central tracking subsystem (CTS), handheld tracking subsystem (HTS), handheld messaging subsystem (HMS), and Web administration subsystem (WAS), as specified below.

- CTS presides over group membership maintenance. It ensures fidelity and correctness of mobile database that records peers' profiles, locations and statuses [16]. It provides basic message relay and offline message services, and special privacy-aware and location-based message delivery services. For system interaction, it offers other subsystems remote APIs to execute actions, e.g., location registration and update, database access, message delivery.
- HTS provides location information about group peers' movements in a request-response manner. A specific location tracking service can deliver subscription-based notifications of location change. For interaction, HTS adopts a handheld-oriented method to update location records in CTS. HTS provides HMS with APIs to locate target peers for later message delivery.
- HMS integrates multifold GUIs for users to easily compose a message, designate a recipient peer and dispatch the message to CTS. HMS supports both text based and vocal message formations.
- WAS supports a Web-based remote OA&M mechanism that is linked up with CTS. It offers configuration and control interfaces for an administrator to remotely manipulate CTS functions and manage group membership.

B. Central Tracking Subsystem

The CTS performs peer group management in a central manner. A CTS runs on a central server with a stationary network location reference, via which any mobile peer can connect to CTS to actively register and update its current geographic and network locations. In addition, CTS can periodically probe mobile peers. The use of both location management strategies ensures fidelity and correctness of data records stored in mobile database.

The CTS secures group communication among mobile peers with social relationship. Any peer can reckon on the *trusty* CTS to relay information and messages to one or all of other peers in the same group. In order to provide a reliable message delivery, CTS supports message queue and retransmission services to sustain peer mobility and unpredictable disconnection. Like the way used in GSM short message service, either pending relay messages or offline messages can be sent out promptly when CTS notices that any target peers appear again, in the event that these peers connect CTS to operate location updates or registrations.

What is more, CTS supports privacy-aware location-based message delivery method [17]. The trusty CTS offers a special location mapping service for peers to hide their precise locations from other peers in a group. Particularly, CTS can generate a dummy location instead of a peer's precise location and announce it to group members. Receiving any message destined to a dummy location, CTS can resolve and translate the dummy location to its acutal one. The location mapping process running at the CTS is opaque to group members. Note that only CTS is the privacy-aware intelligence deployed. The CTS can thus customize the privacy mechanisms without regard to MHDs.

Furthermore, since CTS maintains mobile group management, it provides WAS, HTS and WAS a variety of remote APIs for the use of operations and interactions among subsystems, including group creation and initialization, location registration and update, location database retrieval, text/voice message relay, etc.

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

C. Handheld Tracking Subsystem

HTS, running at the peer side, conducts a symmetric function of location registration and update corresponding to the maintenance of location database at CTS side. Initially, at the moment that a peer joins in a group, a peer sends its peer profile to CTS and then receives from CTS a belonging group profile that contains a list of peers and their locations.

Specifically, there are three different peer roles, i.e., *passive*, *active*, and *supervisor* peers, as defined with different peer profiles. CTS prescribes different group profiles, associated with different access and authority levels, according to peer role differentiation. For example, a passive peer can merely report its up-to-date location and receive relayed messages from others. An active peer can update its location and query about others' locations. Contrarily, a supervisor peer is able to survey all its group peers and exclude any queerish peer.

Observe that message exchange over ubiquitous IP networks practically undergoes a longer round-trip latency. HTS caches a copy of group profile and other peers' information to reduce service delay. However, profile caching in peer side unavoidably induces cache inconsistency. In the literature of mobile database research [16], multi-version [18] and polling are two major approaches used to resolve this circumstance, respectively, in synchronous and asynchronous ways. Our design employs both methods to this end. Hence, HTS applies an *aged* time-based polling way to check with CTS. Oppositely, CTS informs all groups of their updated profile versions after the periodic probing execution.

D. Handheld Messaging Subsystem(HMS)

HMS, running at the peer side, supplies peers message writing, delivery and display operations. The design of HMS provides two kinds of message representation, text based message and vocal messages. HMS processes both in a store and forward way.

- A text-based message resembles a GSM short message. Users input a string by means of qwerty or touch-screen.
- A *vocal message* is specially designed as considering practical mobile communication scenarios and usages. Explicitly, a vocal message could be desirable for mobile peers, such as car drivers and pedestrians, when they are on the move and cannot cautiously type in spelling or operate devices. Rather, recording a voice clip as message content is convenient and easy to use.

Particularly, after a message body is formed and also its target peers are indicated by HTS, HMS sends such a message to CTS which then relays it to target peers. In the meantime, any appropriate message encryption and decryption methods can be enforced to ensure the secure message delivery.

In regard to message delivery among peers, the design of HMS provides several message delivery modes, including *unicast*, *multicast* and *blanket broadcast* (basic modes), and *selective zone*-based broadcast and *hot zone*-based broadcast (advanced modes), as mentioned below. It is noted that the system employs the application-level broadcast delivery paradigm [19][20]. To avoid ambiguity, the terms of multicast and broadcast used hereinafter are not identical to IP multicasting and broadcasting.

1) *Unicast, multicast and blanket broadcast*:These delivery modes are basic since a peer can learn other group peers' locations by the facilities of CTS and HTS. Fig. 3(a-c) show these delivery modes. A peer can unicast a message directly to another peer, or multicast a message to many other peers in the same group. Otherwise, the blanket broadcast is used to send a message to all peers in a group.

2) *Selective zone-based broadcast*: Unlike basic delivery modes, the use of a selective zone-based delivery mode is associated with digital map, graphic view of group peer distribution, and touch-based GUI, in addition to CTS and HTS. Fig. 3(d) illustrates this delivery mode. Specifically, a user can designate a zone on the display screen to cover any target peers of interest. The system correspondingly maps the designated zone onto a set of geographical coordinates in terms of GPS format. HTS then determines a list of which target peers stay in the selective zone according to their locations. Finally, MHS encapsulates this peer list into the specific message. As receiving this message, CTS accordingly relays this message to every indicated peer by the unicast mode.

3) *Hot zone*-based broadcast:The use of a hot zone-based delivery mode is very interesting. It offers an event-driven delayed-action messaging service that is beneficial for many mobile information applications, like location-based instant messaging, and mobile advertising. For example, following the travelling scenario aforementioned in Section II, in case that a preceding peer encounters a traffic jam in some streets, it can highlight a hot zone, covering those streets and surroundings, and warn other group peers not to enter the area. Fig. 3(e) shows this delivery mode. Specifically, a peer draws a hot zone on the map. HMS registers this hot zone at CTS side, by sending a specific message including geographic coordinates of this hot zone. HMS appeals to CTS for later forwarding a specific message to other group peers, at the moment which they enter or leave this hot zone. On behalf of HMS, CTS can continue tracking other group peers and timely inform them of this message.

Note that the hot zone-based delivery runs in an asynchronous way, which is cost-effective as sending messages on demand, compared with the blanket broadcast that informs all group peers in advance. More importantly, a mobile peer is able to reduce both energy and communication costs, since an MHD is battery-powered and somehow has limited transmission capacity.

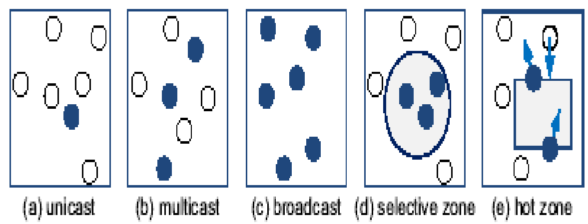

Figure 3. Five message delivery modes

E. Web Administration Subsystem(WAS)

WAS is a Web-based management server that has two major *interface* mechanisms, front-end OA&M interface and back-end database manipulation interface. The former provides a remote interface used to process system configuration and group manipulation, and to conduct interaction between CTS and HTS/HMS over HTTP-based communications. The latter provides an interface used to maintain mobile database. Particularly, since mobile database is associated with CTS, WAS is linked up with CTS to perform mobile database retrieval and maintenance through customized interfaces. In addition, WAS can access historic r*aw* location data and present a graphic view of any peer's movement history.

F. Major Interactive Procedures

This subsection describes several procedures, but not all, to ease understanding of the system development. Following the flowchart of Fig. 5 in top-to-down order, there are four phases corresponding to a peer's activity, and an extra phase for system administration: (1) a peer's group creation, joining and leaving, (2) location registration and update, and subscription-based tracking (3) periodic polling and renewal, (4) location query and mobile messaging, and (5) remote OA&M phases, as mentioned below.

1) Group Creation, Join and Leave:

When a peer asks the system, i.e., CTS, to create a peer group, CTS firstly authenticates this peer's identity by checking its registered record. In this context, only a registered peer (already confirmed by the system) is permitted creating a peer group and serving a supervisor in this group. Namely, a supervisor peer is the first peer in a group. The CTS assigns every new group a unique numeric code, a.k.a., *group code*. The supervisor peer will send this group code to all of its peers which can join the indicated group with this code. When CTS accepts a peer's join request, the peer is replied with a group profile. Later, any group peer can notify CTS of its leaving. So, CTS updates this group information, and then informs other group peers of this event.

2) Location Registration, Update and Tracking:

The location management involves two complementary processes, registration and update. A peer invokes a registration process firstly after it has joined a specific group. This peer lately updates its location whenever it moves to another location. On the other side, when CTS deals with a peer's location registration or update request, it checks if there are any pending messages or offline messages which are destined this peer during the time interval between two consecutive updates. Any unsent messages can thus be delivered to the target peer at this time.

In addition, a peer can subscribe to the location tracking service provided by CTS to notify a subscriber of any events of location change regarding other group peers. This kind of pub/sub service can also be used to report any changes of group statuses. Thus, when a peer receives an event, HMS prompts the notification message on the display.

3) Periodic Polling and Renewal:

The CTS performs a periodic probing process to poll all group peers' statuses in a synchronous way. The probing message contains a *version* flag which is used by the receiving peers to make a version comparison. Accordingly, any peer in a group can know cache inconsistency, if occurred, and dispatch renew requests to CTS. The CTS will authenticate such a renewal and push new records to update the peer's local cache. By the way, if there are also any unsent messages or events for this peer, CTS will send out them together in a batch of messages.

4) *Location Query and Mobile Messaging**:***

The system supports the basic on-demand location query in an asynchronous manner, in addition to the subscription-based method. When a peer queries CTS about another peer's up-to-date location, CTS firstly authenticates the query, retrieves the corresponding record from mobile database, and responds the result to the peer. The peer can cache this result to avoid later repeated queries. Incidentally, the use of either asynchronous or synchronous way is significant, while mobile data service should be costly relatively, empirically depending on the design of service scenarios and use cases.

Formatting a mobile message involves four parts: the assignment of target peers, the checking of target peers, the input of message payload, and message encapsulation. Firstly, HMS determines a set of target peers according to a user's choice of message delivery mode (indicated by using a check list or zone-based selection). Secondly, HMS asks HTS to check the availability of target peers. If some target peer is temporarily unreachable, the user is prompted to enable offline messaging or not. Thirdly, for a text message editing, HMS presents the user a text box to input a string. Alternatively, a voice recording GUI is prompted for the user to generate an audio clip. Finally, HMS encapsulates the message according to a specific structure, and transmits it to CTS. Then, CTS proceeds to the message forwarding task.

5) Administrative OA&M:

The CTS is coupled with a Web server that provides remote login, authentication and verification, and system operation and management interfaces. A system administrator can use any conventional browser to get touch with the server page via which he/she can type in and then *post* specific OA&M action forms to the server. The server is responsible for coordinating OA&M among subsystems, and interaction between the system and its administrator.

IV. PROTOTYPE AND DEMONSTRATION

This section mentions the prototype development and exhibits a real demonstration of developed services and usages with some snapshots to ease exposition.

A. Prototype And Development

The prototype integrates peer-side and server-side software modules in light of design specification. We develop peer-side HTS and HMS software by means of Android SDK 2.0 [15] .They can be deployed on any kinds of MHD platforms which have GPS, Wi-Fi and GPRS/3G network modules, and support Android OS. On the server-side, we implement both CTS and WAS software by using Wamp server and eclipse software on Android OS in general PC platforms. Furthermore, for secure communication, message exchange between HTS/HMS and CTS is conveyed over HTTPs connections with MD5-based authentication to ensure secure message transport service.

B. Scenario Development

The software implementation results in a real application that users can use to experience mobile group communication services. Consider users may be on the move by either walking or various vehicles. Our designs of GUIs and usages avoid sophisticated literal commands and interactive operations, except editing text messages. Most manual inputs can be handled by a finger's touch input on the panel. In what follows, we present several snapshots to exhibit the demonstration.

Fig. 4 illustrates the group creation and initialization. A supervisor peer requests CTS to create a group. After CTS verifies this peer's identity and accepts this request, it replies to the first group peer with a four-digital group code 6142. Later, this peer can invite other peers to join this group with this group code. As a new peer appears in this group, CTS informs other group peers of this new one. Peers reflectively update their map rendering. Incidentally, in this prototype an HMD's unique IMEI was previously registered at CTS, as shown in Fig. 9, for used in the future identity verification. Fig. 5 depicts the usage of delivering text-based and vocal messages. After clicking SendMSG button as shown in Fig. 4(d), a user choose to edit text-based or vocal message. Initially, the receiving peers are included according to which message deliver mode adopted. As a text message, a user can input some words in an ordinary way. Alternatively, a user can instantly generate a voice clip by pressing the recording button, and the vocal message will be automatically formatted after the pressed button is released. The user then sends this vocal message to target peers through the receiving peer immediately prompts the message content to the user.

Fig. 6 depicts the special hot zone-based message delivery. A user directly draws a hot zone on the touch panel and inputs a specific text/vocal message content. The HTS packages the hot zone information and specific message content into a dedicated message and sends it to CTS. Correspondingly, CTS resolves the dedicated message and inserts the hot zone record <Hotzone ID, Name, Range (GPS coordinates), Actions> into mobile database, as shown in Fig. 9. Later, whenever other group peers move into this hot zone, they will receive the specific message sent from CTS on behalf of the original peer.

Fig. 7, 8 and 9 illustrate the friendly OA&M interface and presentation, offered by WAS linked up with CTS and mobile database, herein termed as *CTServer*. As shown in Fig. 7, WAS provides a form used to register any potential supervisor peer's record <MHD's IMEI, Nickname,

Figure 4. Group creation, initialization and joining.

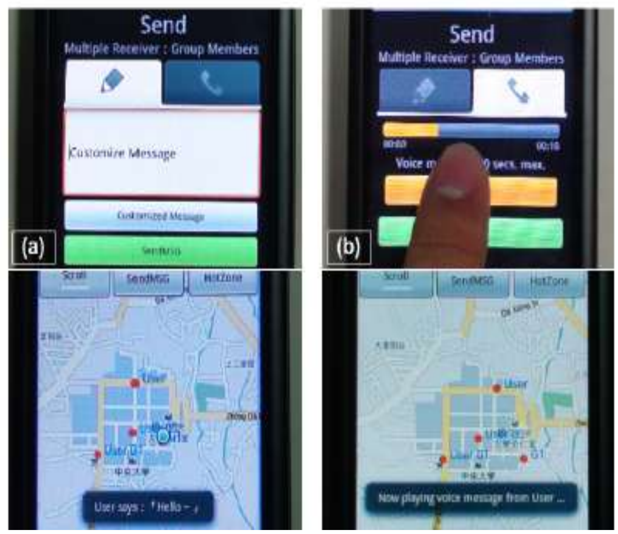

Figure 5. Message sending and receiving: text and vocal messages.

Figure 6. Hot zone-based message delivery.

Description, Actions. Fig. 8 shows a group management and control page. Wherein, an administrator can view all groups' profiles, every group's peer list and its peers' geographic distribution. In addition, the administrator can invoke remote control actions via this page, for example, kicking off peers, and modifying group-specific and peerspecific data. Finally, Fig. 9 presents an additional management page that is mainly used to display a particular peer's or group's location history in a graphic view, and also to browse a detailed message history for reference.

Figure 7. User registration and administration.

V. CONCLUDING REMARKS AND FUTURE WORK

This paper has proposed the system architecture, functional components and message communication protocols for designing mobile group communication services in ubiquitous IP network environments. Based on the proposed framework, our efforts have developed the location query and tracking services, mobile text-based and vocal messaging services, and various message delivery modes. We have implemented the prototype by means of non-proprietary open software packages, e.g., Android SDKs and Wamp server and Eclipse platform. Demonstration has shown the scenario realization on target MHDs in present network environments.

At present, we proceed to extend the primary system architecture in supporting peer-to-peer communication among group peers. Rather than replacing the central server by CTS, we would like a hybrid design to more accentuate the potential of multimedia content and resource sharing among peers, in addition to mobile messaging service. Moreover, we will study new mobile and location-based information applications on the proposed system framework. Furthermore, additional security packages and key cryptography technologies will be examined and applied in place to strengthen the system security and robustness.

Figure 8. Group profile and management.

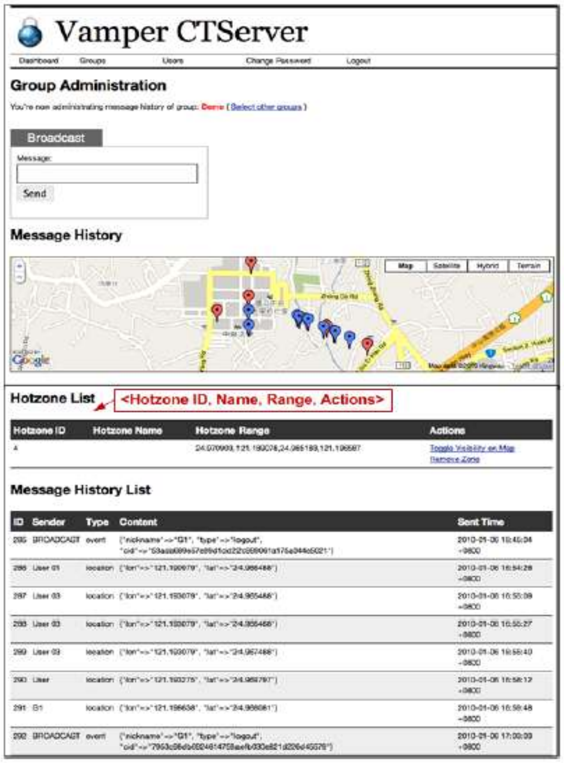

Figure 9. Group administration and data log**.**

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