BASA: Building Mobile Ad-hoc Social Networks on Top of Android

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Abstract

Mobile ad-hoc social networks (MASNs) are emerging as a self-configuring and self-organizing social networking paradigm, which enhance local interactions among mobile and handheld device users. However, the MASNs cannot be directly derived on demand for various Android systems from existing social networks (SNs) without having access to end-to-end IT network infrastructure. In this article, we propose a detailed solution called BASA which would help in rapidly building local mobile ad-hoc social networks on top of the current Android platform. BASA establishes a four-layer system architecture according to the underlying challenges and requirements in MASNs. BASA is implemented in an EU project named "SOCITIES." Our prototype shows that BASA is flexible to expedite various services.

The proliferation of consumer-oriented communication technologies across the Internet and mobile communication has fostered growing attention to social networks platforms (SNs), and expedited a large-scale of SN services on the Internet. These SN services help connecting people from different geographic location, facilitating smooth function of their work, different moods of communication and socialization. Despite the widespread success of social networks, they have certain limitation which can be further boosted with the proposed new design solution. Firstly, people often demand a kind of ad-hoc social networks to strengthen local communication with proximal contact and closeness on local address. In scenarios such as conferences and expositions, the participants might exchange information and share documents with new partners. However, there is no direct way in current social networks to facilitate local social communication. Thus, the participants might give up exploiting interpersonal affinities for personal benefits. Although, face-to-face communication is a way, but it is less useful for file sharing and group discussions, where social media is the main goal on social network. Secondly, the existing SN services implicitly assume that the Internet or cellular network infrastructures are always available. This assumption, however, may not be held true at all time owing to the blind network spots, device heterogeneity, and security considerations. Thirdly, it is time-consuming to build and manage local SNs in Android platforms without general development schemes. Each service provider accomplishes local SN functions by individual schemes, incurring much repetition of work and heavy human resource costs~\cite{Katsaros}. Additionally, Google Android has provided developers with common API libraries and development tools necessary to build, test and debug applications. However, it does not provide support for local social community orchestration.

Recently, the MASNs become prevalent for the ubiquitous usage in laptops, smart phones and touch PADs. The MASNs refer to a kind of self-configuring and self-organizing social networking paradigm, which set up local social communication via mobile devices without utilizing the underlying infrastructures. They bring both convenience and challenges to SNs. On one side of the spectrum, the MASNs relax the requirement that communication infrastructures are indispensable. By short-range communication techniques such as Bluetooth and ZigBee, the MASNs establish local community. On the other side of the spectrum, they impose new challenges on SN services due to local socialization and user mobility.

The related studies of MASNs cover a series of areas, mainly comprising of community detection, evolution and data transmission. There are some schemes close to our work. Table 1 summarizes the MASN services and applications, showing that the MASNs still need to be more investigated. To distinguish our work, we address a fundamental problem of fast building MASNs on demand with minimal infrastructure support. Our work is implemented in an EU joint-investigative project entitled "SOCITIES" [2], which aims to achieve the following key objectives.

- To offer a novel and reliable solution to work, communicate and socialize by community creation, management and communication in social community spaces.
- To provide good usage for both individuals and communities — based on proactive smart space behaviors and dynamic sharing of community resources across boundaries.
- To design a robust, open and scalable system for self-orchestrating community smart spaces in the MASNs.

To pioneer the work of SOCIETIES project, we propose a solution named BASA: Building mobile Ad-hoc Social networks on top of Android platform, where BASA applications behave in a consistent fashion across heterogeneous devices that can run on Google Android systems. The proposed scheme simplifies the social networking development in the MASNs. It allows SN service providers to rapidly build non-infrastructure oriented MASN services. BASA enables devel-

Representative Projects					
Categories	MIT Serendipity [3]	MobiSoc [4]	MobiClique [5]	SpiderWeb [6]	Crowd [7]
Device dependence		✓	✓	✓	✓
Infrastructure dependence	✓	✓	✓	✓	
Community orchestration					
Cloud-based storage			✓		✓
Scalability	✓	✓		✓	✓

Table 1. *Summary of MASN services and applications.*

opers to react on user requirements rather than cumbersome technical details of mobile systems. We further develop a prototype for SOCIETIES project, showing that BASA is flexible to support various community-based MASN services.

The remainder of this article is organized as follows. We overview the challenging issues in the MASNs. We introduce BASA in detail. We report the experiments. We then raw conclusions.

Challenging Issues

The social network services are getting ingrained into our daily life and people all across the world are getting engrossed on it for day to day communication. When the mobile users flock together, the MASNs usually come to picture. The potential growth of the MASNs is huge along with the constantly growing penetration rate of mobile devices. Mobile devices are equipped with mobile communication systems, and short-range wireless communication protocols. These devices are capable of accessing the Internet and SNs, and operating on the third-party value-added services. Moreover, they store their owners' information concerning profiles, messages, photos and relationships.

In general, the MASNs significantly differ from previous SN efforts. They raise certain unique challenges as described below.

- Minimal infrastructure requirement: We are often in a dilemma that there is no good concrete and robust solution for group discussions and activities in conferences, shows and expositions. In many scenarios, the Internet and cellular networks may not be always available, or they may be excluded owing to the incompatible mobile systems, limited network bandwidth, or security and privacy concerns. We indeed expect to interact with people in proximity without accessing the Internet or other value-added communication services. On the contrary, the MASNs are an attractive solution to user interaction in proximity, which is not closely bounded to any IT network infrastructures.
- Dynamic community self-orchestration: In SNs, the social communities are established based on the existing SN services, no matter how far away the community members are in real world. For instance, a user may join a travel community on Facebook to track a photo sharing thread. Thus, the SNs manipulate the social communities by service providers rather than community managers. However, this kind of hierarchical management control cannot satisfy the requirements of the MASNs, where users call for local social communities for temporary communication and information sharing tasks. Because the ad-hoc communities are built as required, their creation and orchestration should be able to cope up with the dynamic nature of MASNs.
- Device-independent design: Device heterogeneity is another concern derived from social computing and network convergence. In order to provide consistent user experience across heterogeneous devices, the MASNs require a device-independent design, where the system would be independently able to tackle the challenges in adapting to new running application to the current device. Correspondingly, computer programmers would be able to concentrate on the logic design of the MASN applications.
- Scalability: It dramatically affects the performance of the MASNs applications from two perspectives. The macroscopic perspective denotes that the social computing services may involve large group of mobile users, resources and communication on an unprecedented scale. The microscopic perspective represents that handheld devices usually suffer from the limited computational and communication capabilities.

BASA: Building Mobile Ad-hoc Social Networks on top of Android

In this section, we propose BASA — Building Mobile Ad-hoc Social Networks on top of Android, which enables local communication without utilizing the underlying network infrastructures. The proposed solution assists developers in rapidly creating new MASN services and applications on demand.

Overview

Figure 1 presents the main functions of the proposed scheme, including two major functions for a MASN service, namely, communication and socialization. The former function is to keep communication for inter-connected users in proximity, whereas the latter function is to provide social services for user interaction. Specifically, BASA is designed to fulfill the following functions:

- To create MASN applications: BASA is capable of creating MASN applications automatically or manually for handheld device users. These users are physically in close proximity with the similar interests in certain situations. They are connected by short-range communication protocol stacks.
- To customize MASN applications: According to user intents, interests and preferences, users personalize their MASN applications to better suit their needs.
- To orchestrate MASN events: The events refer to something that occurs at a certain time in social networks. Common events mainly consist of community creation, community shutdown, community merge, member joining and information propagation. The community events correlate with communities and individuals. In order to detect the status of MASN applications, BASA copes with the events timely.
- To support value-added community services: BASA supports the third-party community services for advanced information sharing on user profiles, micro-blogs and product ratings from online social networks.

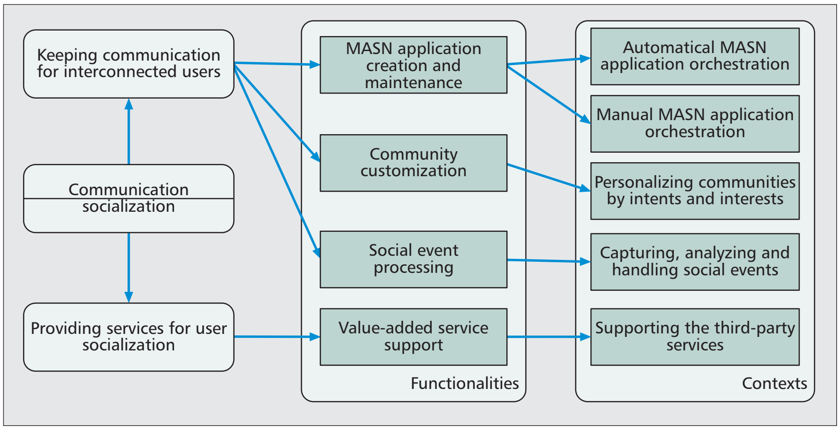

Figure 1. *The overview of BASA scheme that achieves two crucial functions – short-range communication and local socialization.*

Network Model

BASA is a loosely-coupled distributed system across the network with shared memories. Mobile users are regarded as equivalent nodes that may frequently move across the network. In general, the Internet and cellular systems are not always available in the scenarios where BASA applies to due to the constrained bandwidth, and security and privacy concerns. The bidirectional communications suffer from finite but unbounded message delay. Figure 2 illustrates the preliminary network model of the proposed scheme, which is end-to-end integration of social networks and opportunistic mobile ad-hoc networks (MANETs).

- In MASNs, mobile devices are equipped with a couple of short-range communication stacks and protocols. Each device in the network discovers other terminal devices connected within the network, whose owners share similar interests within its close vicinity and proximity using Wi-Fi or Bluetooth protocol. It establishes direct connections between itself and its neighbors. Then, it would organize the members in a tree structure and shares all the required information with each member in the network. Given an ad-hoc network, its members cannot directly communicate with the other nodes out of the local network. Notice that these ad-hoc MANETs are generated in specific scenarios, e.g., expositions, where users opportunistically encounter for some common goals.
- In contrast, mobile devices in SNs are connected via online social networks. The online services are constructed on the basis of the Internet, or other underlying IT infrastructures as required. This kind of socialization takes place in virtual environments with ignoring the local communication.

The MANETs and SNs jointly form the integrated MASNs. The physical or logical connections between the MANETs and SNs are not mandatory. In a sense, the MANETs strengthen the "*local interaction*" on physical environments, while the SNs highlight the "*global interactions*" around the world primarily via the Internet.

System Architecture

To realize the functions of BASA, Fig. 3 shows a hierarchical system architecture, mainly involving device, network, social and application layers. There is a dependency between two adjacent layers.

BASA is dedicated to solving the challenging issues imposed by MASNs as described below. The device layer primary goal is to achieve the device — independence connection and scalability. The network layer is targeted to achieve interconnection with minimal IT infrastructure support. The social layer intends to realize the self-orchestrating socialization capability in MASNs. The application layer provides various value-added social services beyond the above three layers. Besides, BASA also incorporates the other features from MASNs such as user mobility and limited system resources into the design consideration.

Device Layer — This layer primarily executes BASA applications on mobile or handheld devices, through which mobile users access MASN services and socialize their activities. This layer is composed of several components, which has the following features.

- Runtime support has an in-built software package that supports the runtime execution of BASA applications. It also facilitates the installation, configuration and deletion of the applications on handheld devices. Runtime support is a *de-facto* standard to overcome the device heterogeneity as encountered normally.
- User interfaces are a set of sophisticated and powerful component models for building the interaction interfaces on certain devices. Additionally, BASA allows developers to create their own interface components for rich applications. Android systems power thousands of heterogeneous devices with various hardware, ranging from small PDAs to large tablet TV sets. To promote a consistent user experience, BASA customizes some specific classes to build unified user interfaces that adapt to various screen sizes and density combinations.
- Application programming interface includes a set of algorithms for allowing mobile devices to communicate and exchange message with the network layer, and enabling users to execute actions on mobile and handheld devices. Thus, with the support of these algorithms, mobile users would timely know the progress of their actions by the interfaces that are automatically updated.
- Repositories are the place to store several information of BASA applications. BASA uses a mix of internal and external storage to save persistent data in databases, files and preferences. These data usually consist of user account information, profiles, recent actions, system status and resource allocation. Furthermore, BASA provides several proprietary functions to efficiently store and retrieve data from cloud servers.
- Requirements are the files that represent the view of BASA applications. They declare all application requirements, such as the application resources, the minimum version of

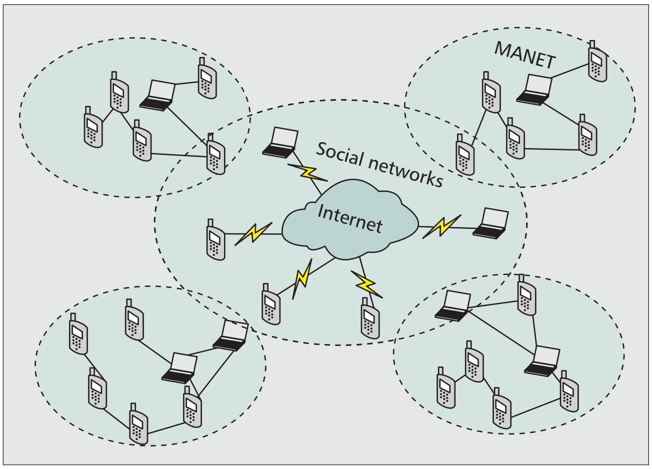

Figure 2. *The preliminary network model of the proposed scheme in a bird's eye view.*

mobile systems required, and hardware configuration required. They also declare the application components.

Network Layer — In addition to the standard network connections, this layer offers rich mechanisms for mobile devices to connect and interact with other counterparts over Bluetooth, Wi-Fi, SIP, and USB. It is made up of the following components.

Network connection. Besides the standard communication with the Internet and online SNs, BASA allows handheld devices in close proximity to directly communicate using short-range communication stacks and protocols that are in the same local network or in different network. Specifically, a device initiating a network connection will perform a series of actions in sequence viz. discovering nearby devices, subscribing to their published services, determining the connection details, and creating connection wirelessly.

Ad-hoc network management establishes local mobile ad-hoc networks for mobile device connections.

- Ad-hoc network establishment. In a specific area, BASA detects mobile devices in the vicinity of active users. It gets a list of nearby devices connected in the network. By virtue of the short-range communication protocol stacks, BASA creates a mobile ad-hoc network.
- Ad-hoc network maintenance. BASA periodically conducts common network operations with the basic elementary functions for network discovery of nodes, services, and connection changes while minimizing the network costs.

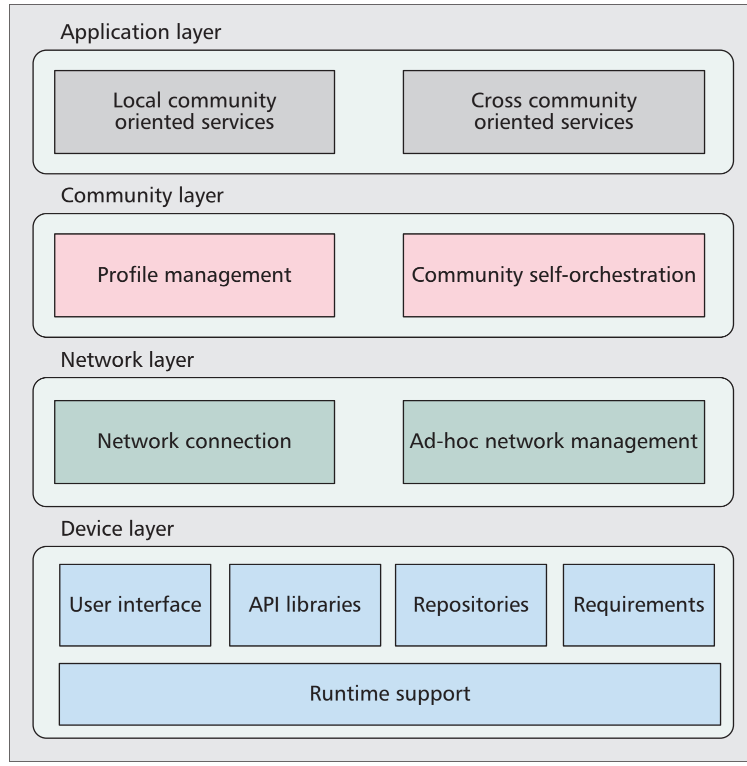

Figure 3. *The BASA system architecture.*

Community Layer — The community layer mainly performs community and member management operation. Once a mobile device is connected to an ad-hoc network, it will launch a particular application. When the application runs, the user will be required to perform the following two major functions.

•Profile management identifies, authenticates and maintains the information of mobile users connected to the MASNs. It aggregates user profiles, stores these information to repositories, and grants other users with access rights. It mainly involves the aggregation, storage, authorization and merge of user profiles.

•Community self-orchestration is dedicated to community establishment and maintenance.

–According to the profiles, intents, and preferences of nearby mobile users, BASA provides the function of communication initiation and creation. Active users recognize the geographically neighboring users with similar interest and they can create local social communities and send invitations to the users whose profiles match the community profile. The new user will join the community by accepting the invitation. Once a user becomes a community member, he/she can interact with all other members in the same community.

–This component discovers the services offered by the communities and publishes them within the source community. Through BASA, mobile users can leverage local communities for instant sharing of social media. This component also monitors the communities formed in the MASNs and takes corresponding actions for community changes. Because mobile devices are with limited computation and communication capabilities, BASA adopts a hybrid network structure as shown in Fig. 2, where some powerful PDAs or smart phones are chosen to handle community events raised by neighboring mobile and handheld devices.

Application Layer — This layer allows developers to create innovative BASA applications based on the need of local social community requirement, using a set of reusable components, together with the program guidelines. In general, a BASA application is composed of one or more application components. BASA borrows the similar design principles and patterns from Google Android platform where activities, services and receivers are three core components. These components behave significantly different, and are activated by dedicated messages.

Local social communities are organized in the communication layer. Information sharing within a local social community saves lots of network communication costs. To customize these user experience, BASA designs two kinds of prime services.

•Local community oriented services serve the users who belong to the same local social community. Owing to the fast network bandwidth and direct short-range communication, BASA can support network-intensive applications and services, such as video streaming and large-scale document editing.

•Cross community oriented services satisfy user requirements across multiple communities spreading across the network, which is highly significant for some important applications such as infectious disease surveillance. Hence, BASA designs lightweight services including instant message and audio sharing.

Experiments

In order to evaluate BASA, we develop a prototype based on SOCIETIES project. In particular, we have design an experiment according to the functions encapsulated in BASA. We have set up a testbed covering 300m × 60m and

	MIT Serendipity	MobiSoc	MobiClique	SpiderWeb	Crowd	BASA
Architecture	Centralized	Centralized	Distributed	Distributed	Centralized	Distributed
Neighbor discover	Bluetooth	Wi-Fi	Bluetooth/Wi-Fi	Bluetooth	GPS/Wi-Fi	Wi-Fi/ Bluetooth
Community detection	Degree centrality	Betweenness centrality	Tie strength	User similarity	Tie strength	Similarity
Content distribution	Flooding	Epidemic routing	Flooding	Flooding	Tree	Tree
Local community	Yes	Yes	N/A	N/A	N/A	Yes
Mobility patterns	Behavior traces	N/A	N/A	N/A	N/A	N/A
Social patterns	Contacts, calls	Co-location	Co-location	Links in SNs	Behavior traces	Co-location

Table 2. *The comparison of BASA and existing schemes.*

invited 20 faculties and students as mobile users. Users have performed their daily activities as usual. Every time users are classified into 3 up to 8 groups based on their physical proximity. Each user carries a mobile phone running Google Android 2.0 system. Each device is equipped with Wi-Fi, Bluetooth and 4 GB onboard RAM. We have selected SQLite as the main Android repository because it is zero-configuration and lightweight for mobile terminals. We inherit the same implementation as the Android system for the other designed components.

Overall Performance

In order to evaluate the performance of the proposed design, we have selected the following parameters, namely, the degree centrality, tie strength, betweenness centrality, and similarity as social metrics. These metrics are defined as [8].

Table 2 illustrates the technical comparison for previous efforts and BASA. It indicates that BASA is designed for local community discovery and information sharing without network infrastructures.

Prototype Design

We have further developed a prototype to validate the BASA application. We have introduced the design by layer.

Device Layer — BASA implements a system-level and application-level runtime support for its applications to achieve device-independence across various Android-enabled handheld devices. The former support provides supports for underlying graphics rendering and computer operations at the core running level of Android systems. The later runtime support handles runtime device changes at the application level of Android systems. When BASA detects changes on the devices, it performs two major options: restarting the application automatically, and handling the changes manually when the users need to save the proprietary data and retrieving the same. For user interface, BASA evolves and develops itself for users in an intuitive and simple manner. Users have quick access to the key features of BASA applications using a mix navigation of action bars and buttons. These key features are organized as four top-level user interfaces viz. *Profiles*, *Community*, *Friends*, *Applications*. To enable convenient access, BASA provides a hybrid navigation systems using *Home* and various contextual menus. The GUI based services in BASA can be extended for personalized inputs, dictionaries, spelling check and multi-touch features.

BASA strictly follows the four-layer system architecture. That means when a user is performing an action for a particular layer, he/she cannot access the functions of the upper layers. For example, a user runs a BASA application without establishing MASNs, he/she can only perform local profile management.

Additionally, BASA releases many static libraries for programmer community to build dynamic user application interfaces, share contents among applications and optimize the system performance. It also offers developers with consistent and formatted requirements to suit their local needs.

Network Layer — This layer addresses the communication among user interaction in MASNs. It manages the exchanged information that reflects user actions on their connecting devices. BASA extends the communication in Android over Wi-Fi, USB, SIP, Bluetooth and TCP/UDP. As most network-connected Android applications leverage HTTP to exchange data. BASA provides a series of network API by encapsulating the fundamental functions into *Conventional HTTP* and *Apache HTTP* packages for HTTPS, streaming, IPv6 and connection pooling.

The network layer is in between the device layer and community layer. Therefore, BASA offers a mechanism for the network layer so that it can send and receive data simultaneously. Considering the state-of-the-art of Android systems, BASA handles two distinct problems in the implementation of the network layer.

- Android has an inherent limitation that there is no ad-hoc function such that neighboring devices cannot forthwith form communities. To this end, BASA boosts Android systems in such a way that a device can locally discover its neighboring devices and then create local community. The enhanced mobile ad-hoc and social networks for Android devices has no interference with the operations in the network layer and the other layers within BASA.
- The communication paradigm should improve its capability since Android is constrained by its limited power, computational and communication capabilities. In BASA, Android users are distributed in small areas and physically close neighbor. They might form a cohesive social community with shared interests, preferences and behaviors. BASA further develops a lightweight client-server communication architecture, integrating the table-based database SQLite for local communication and files for cloud synchronization and backup.

Community Layer — BASA implements two components for the community layer to cope with the community self-orchestration viz. bootstrapping and community management. The former component authenticates the users before successfully allowing the users to update their personal profiles including account and preferences. It also provides users with available neighbors in their close vicinity to share information. The latter component handles the community creation, maintenance and deletion. It is being achieved by two ways — automatic operation and manually maintenance. Users in the same community can share files and launch group discussions.

BASA not only works for local social community, but also supports the social networks via the Internet. To be more precise and simple, it enables the local interactions within the community and the holistic interactions across the world.

Application Layer — BASA employs this layer to support various applications for handheld device users. It allows the verified users to access the community services available within the network. When a verified user performs any actions on the local social community, the associated options will appear. When a user selects a community member option, a member list will be displayed to show all the attached intra-community members; when one of the members is selected, the communication option will be displayed to present all the available operations (e.g., chat, block and photo sharing) for the end user. The wire-frame for a user accessing its community and its community members are shown in Fig. 4.

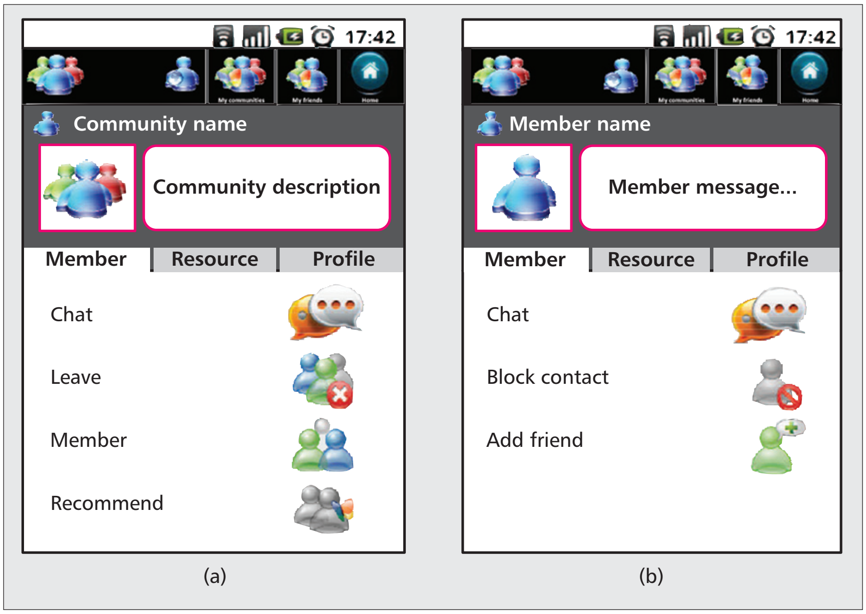

Figure 4. *Snapshots of a user accessing the community and a community member: a) community snapshot; and b) community member snapshot.*

Conclusions

The mobile ad-hoc social networks are becoming a fast growing trend recently. In this article, we have proposed a solution called BASA to build mobile ad-hoc social networks on top of Android. BASA enables the developers to rapidly build prototypes for the local social networks using handheld devices. We are working on BASA for a generic toolkit for both Google Android and Apple iOS.

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