An Agent-based Platform for Ad-hoc Social Networking

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Abstract. Social network services such as Facebook, MySpace or Twitter support more or less permanent social relationships, where user interaction takes place via fixed or mobile access to the Internet. However, in many situations social relationships are ad-hoc (i.e., set up by (mobile) users located in a limited geographical area during a certain period in time). To effectively support this kind of social relationships, we propose an extension of basic social networking model – the ad-hoc social networking. This paper defines the model for ad-hoc social networking, describes functionalities and architecture of a platform for ad-hoc social networking and explains why software agents are opportune technology for platform implementation. Finally, paper presents several applications of ad-hoc social networking.

Keywords: ad-hoc connections, social network service, mobile user, user agent, user collaboration, smart community.

1 Introduction

Social Network Service (SNS) on the Internet, supported by web-based platforms such as *Facebook*, *MySpace*, *Twitter* and others, includes display of a user and his/her social connections, as well as additional services that allow him/her to interact through various forms of network-enabled communication. Social relationships established by SNSs are based on ego social networks[1] – every user is building his/her own social network by defining connections with other people. Consequently, a fundamental entity of a social network is an individual. However, SNSs are not focused on the individuals, but on relationships among individuals – they enable information exchange and cooperation among users within a social network which was built by an individual (i.e., within one ego social network), or, among social networks of different users (i.e., among multiple ego social networks). Consequently, user cooperation possesses characteristics of a *smart community* [21], although the initial purpose of social networking was creation of a user's ego social network. Moreover, if users are represented within an SNS with their personal software agents,

[1] Note that the structure we refer to as an *ego social network* differs from a structure known in literature as an *ego network* [4]. While the ego social network consists from the set of nodes with direct ties to a focal node (called "ego") and only the set of corresponding ties, the ego network additionally contains the set of ties among non-ego members.

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then a multi-agent system implementing an SNS possesses characteristics of a *collective computational intelligence* [20].

SNSs on the Internet support more or less permanent social relationships, where user interaction takes place via fixed or mobile access to the Internet. However, in many situations social relationships are ad-hoc (i.e., set up by (mobile) users located in a limited geographical area during a certain period in time). Such an appearance of a mobile user in a specified location during a specified period in time is often associated with a certain social event (e.g., business/academic event such as a meeting/conference, everyday event such as a football match, or disaster event such as a road accident). To effectively support this kind of social relationships, we propose an extension of basic SNS model – the *ad-hoc social network service* (ahSNS). A platform for ad-hoc social networking should enable three features:

- creation and membership management for an ad-hoc social network (ahSN),
- transfer of user profiles and other user-related information between a SNS and an ahSN, and
- interaction in the ahSN via mobile network.

This paper, i) defines the ahSN paradigm, and, ii) explains why software agents are opportune technology for ahSN implementation. Firstly, Section 2 gives an overview of a related work. Afterwards, Section 3 derives a model of ad-hoc social relationships and Section 4 presents interactions in ahSN. Finally, Section 5 describes the architecture of a platform for ad-hoc social networking, while Section 6 concludes the paper and announces our future work.

2 Related Work

Various combinations of a user:

- location in a particular period of time;
- knowledge/skill/experience/interests, and
- social relationships

are already recognized by SNSs on the Internet as one of the major pillars for their future business models, as well as by academia as a hot research topic.

Facebook, a leading SNS with over 500 million users, introduced *Facebook Places* [8], a supplementary service which enables *Facebook* users to:

- “easily share where they are, what are they doing and the friends they are with right from their mobile”,
- “never miss another chance to connect when they happen to be in the same place at the same time as one of their friends”, and
- “find local deals by checking in to get individual discounts, sharing savings with friends or earning rewards for repeat visits”.

Furthermore, *Foursquare* [9] and *Gowalla* [10], a SNSs devoted exclusively to mobile users, have been in public use since 2009 and already have reached 5 and 1 million users, respectively. During registration procedure a new *Foursquare/Gowalla* user has an option of importing his/her friends from other SNSs (such as *Facebook* and *Twitter*). *Foursquare/Gowalla* users publish their current location (automatic “checking-in” based on current GPS-location) and post location-related comments.

They are encouraged to do that because not only they can easily connect with friends nearby but also they get rewards in form of a certain "badge" (e.g., *Foursquare* user will be the *Major* of a place if most times reported in this area).

There is also a number or related research projects. For example, in [18] authors present a graph analysis based approach to study social networks with geographic information and new metrics to characterize how geographic distance affects social structure. Furthermore, the Stanford's Mobile and Social Computing Research Group developed Junction [13], an infrastructure designed to support *partyware* (class of social software that assists users in their real-world social encounters). In [11] authors propose the MobiSoc middleware which provides a common platform for capturing social state of physical communities by learning patterns from the geo-social data and incorporating this new knowledge with the social state. Another project, called Social Serendipity [7], applies Bluetooth technology for detecting other nearby users (by calculating similarity score between user profiles and behavioural data) and uses it to prompt informal interactions between nearby users who do not know each other.

3 A Model of Ad-hoc Social Relationships

An ahSNS can be created as a *closed* or an *open* SN. A *closed ahSN* includes following two features:

- definition of an ahSN initiator (e.g., user u_i), and
- automatic invitation, by the initiating user u_i, of certain SN-members for joining the $ahSN_i$, their registration to the $ahSN_i$ and, finally, direct interconnection of all users in the $ahSN_i$.

An *open ahSN* includes one additional feature:

- registration of non SN-members to the $ahSN_i$ and direct interconnection with all users in the ahSN. A registration of non SN-members must be approved by the initiating user u_i.

It can be noted that the initiating user u_i manages the $ahSN_i$'s membership, regardless of the fact whether the $ahSN_i$ is a closed or an open ahSN.

A graph describing ahSN is a *complete graph*[2], while a geodetic distance between all pairs of users in the $ahSN_i$ is equal to one (1) – both facts are consequences of direct interconnection of all users in the ahSN. This is also the reason why adjacency matrix [12] of every ahSN is identical – with all non-diagonal elements equal to one (1) and all diagonal elements equal to zero (0). All that simplifies a formal definition of an ahSN - we can define ad-hoc social network $ahSN_i$ as:

$$ahSN_i = (u_i, u_j, u_k, u_l, u_x, u_y). \quad (1)$$

In the $ahSN_i$ defined with equation (1) user u_i is an initiating social network member, while users u_j, u_k, u_l, u_x and u_y are non-initiating social network members. A user is represented within an ahSN with a profile, according to the following rule:

[2] Complete graph is a simple graph in which every pair of distinct users is connected.

- *SN-members of an ahSN* – ahSN-profile is imported from a user's SN-profile (under the control of the user), and
- *non SN-members of an ahSN* – user creates an ahSN-profile from the scratch.

A member of an ahSN should be able to export his/her ahSN-profile to a certain permanent SN, such as *Facebook*.

4 Interactions in an Ad-hoc Social Network

Various SNSs support different modes of interactions. For example, *Facebook* enables its users very rich selection of communicating mechanisms – they can interact both asynchronously (via *private messages* to another user/group of users by using *Messages* application; or via *public messages* to another user by writing to that user's *Wall* application) and synchronously (via *private messages* to another user by using *Chat* application). On the other hand, *Twitter* enables its users only to post and read short messages (up to a maximum of 140 characters long) called *tweets*.

An ahSN is an ad-hoc community in which interactions can be twofold:

- *each-to-each communication* – public message published by one ahSN-member and broadcasted to all other members of the ahSN, and
- *one-to-one communication* – private message sent by one ahSN-member to another.

The basic form of interactions is via public messages, because an ahSN is established for certain purpose or reason which is common to all members. Public messages are published via a common available medium and broadcasted to all ahSN-members (alternatively, ahSN-members can only be informed about the publication of messages via a message notification). Message notifications, as well as public and private messages, could be distributed in the mobile network via SMS (*Short Message Service*) or MMS (*Multimedia Messaging Service*).

User interaction within an ahSN should have i) *better availability*, ii) *lower costs*, and iii) *greater energy efficiency* than those offered by "ordinary" SNs. For all three reasons, it is rational to locate the ahSN server closer to users and make it almost immediately available for the mobile network that geographically covers the location relevant for the ahSN.

Service availability is critical for situations such as (natural) disasters, when the global connectivity required for the SNSs, as well as communication in general, is difficult or impossible to achieve. Consequently, ahSNSs can serve as support for the disaster management processes.

Service costs are reduced because users need to connect to the SNS web-site only while creating an ahSN (i.e., during invitation and registration of new ahSN-members, including the import of users' SN-profiles).

Through a reduction of the number of communication and server systems mediating the service, achieved through replacing a remote service provisioning paradigm with a local service provisioning, ahSNSs become *green services* characterized with lower energy consumption than "ordinary" SNSs. Additionally, energy efficiency of ahSNSs can be additionally increased by using short-range communication technologies (e.g., Bluetooth) for communication among ahSN-members.

Furthermore, user interaction within an ahSN can be enhanced by supplementary services, such as:

- *meeting and group facilitation* – scheduling of activities, temporal and spatial arrangement of the group according to specific knowledge/skill/experience,
- *collaborative download* – piecewise download of a specific document by group members and mutual exchange of pieces in order to merge them into a full document,
- *social search* – search for new members fulfilling some knowledge/skill/experience criteria or sharing some common interest, and
- *buyer coalition formation* – grouping members in order to reduce price or take advantage of volume discounts.

5 A Platform for Ad-hoc Social Networking

We have defined a model of ad-hoc social relationships, procedures for building an ahSN and rules for communication among ahSN-members. Now we will describe architecture of a platform for ad-hoc social networking and present several ahSN services we designed and implemented.

5.1 An Agent-based Architecture of a Platform for Ad-hoc Social Networking

From the architectural perspective, a platform for ad-hoc social networking consists of following components (
Fig. 1):

- Client application – *ahSNS application*,
- Server with basic and supplementary services – *ahSNS server*,
- Social network database – *ahSNS application database*, and
- Client application distribution entity – *ahSNS application distribution store*.

Users interested in using ahSNSs firstly have to download the *ahSNS application* from the *ahSNS application distribution store* (e.g., *iTunes Store*, *Android Market*, etc.). Now they can invite other users (or be invited) to build a certain ahSN, according to procedures defined in the Section 3. While registering to the ahSN users SN-members can import their profiles from existing SNSs (e.g., *Facebook*, *Twitter*, etc.). When registered to certain ahSN, users can utilize its basic and supplementary services via mobile network.

Software agents are opportune technology for the platform implementation because they enable high-level of automation for users while preserving their privacy (regardless mobile device they use), as well as seamless communication through the network (they take care of all protocol adjustments, e.g., SIP-to-ACL (*Session Initiation Protocol* to *Agent Communication Language*) message conversion) [1]. The following types of agents are needed for the platform implementation:

- *User Agents* (UA) – implemented as a part of ahSNS application. User Agents enable their owners (semi-)automated interaction with ahSNS Agent. Moreover, as they are trusted entities for their owners, they enable automated profile import/export between SNSs (for users SN-members) and ahSNS. User Agents can learn user preferences and habits over time and adapt according to them if necessary.
- *ahSNS Agent* (SA) – implemented as a manager of ahSNS server. The ahSNS Agent coordinates activities within the ahSN server, gives tasks to specialized agents and serves as a gateway between User Agents and the ahSN server, and
- *specialized agents* – implemented as a part of ahSNS server, every specialized agent is in charge of one basic or supplementary service. Specialized agents receive tasks from the ahSNS Agent, execute them, refresh the ahSN database and return the result to the ahSNS Agent (if needed).

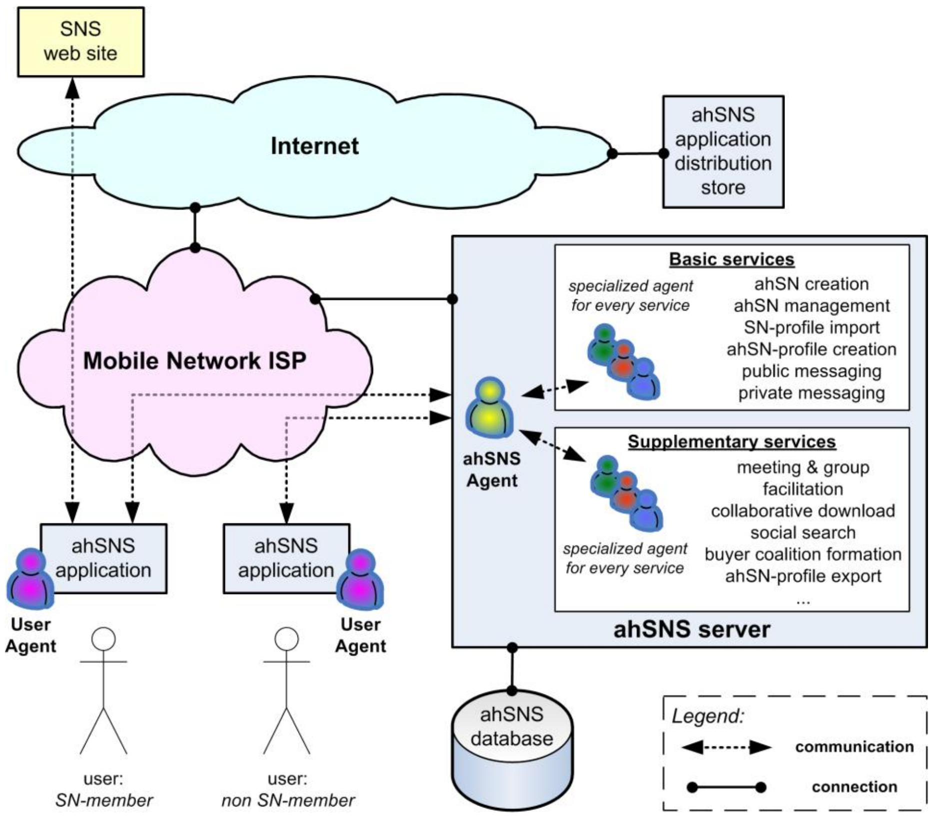

Fig. 1. A platform for ad-hoc social networking

5.2 Proof-of-concept Ad-hoc Social Network Services

We already used JADE agent platform to implement a number of ahSN services. We will present multi-agent systems that enable: i) session mobility in next-generation network (NGN), ii) group-oriented service provisioning in NGN, and, iii) *Collaborative Urban Computing* (CUC) service.

Agent-based Session Mobility in Next-Generation Network. Session (mid-call) mobility occurs when a user changes a terminal, moves to another network, or switches to another network interface during an on-going session. After the mobile user has obtained a new IP address it re-invites the correspondent host in order to re-establish communication.

Possible ahSNS scenario can be the following. Agent UA_{Bob}, Bob's personal agent, i) enables specialized agent on ahSNS server (e.g., Viber Agent, VA) to track Bob's location, and, ii) activates a rule according to which VA creates and manages ahSN called "Bob's Viber Network". This ahSN consists of all Bob's contacts from his iPhone phonebook who have currently active Viber[3] application. At the same time Bob, who also installed Viber application on his iPhone, joins ahSN "Bob's Viber Network" whenever he is at work or at home (i.e., places with WiFi coverage). The VA ensures that Bob, when at work or at home, conducts all his calls to other users from "Bob's Viber Network" via Viber application, consequently reducing Bob's calling costs. Moreover, VA is also capable of autonomously converting non-Viber calls into Viber-calls (and vice versa), as a consequence of i) Bob's mobility, or, ii) change in the structure of ahSN "Bob's Viber Network".

We utilized the LocalNote service [5], a location-triggered instant messaging service that provides a mechanism for sending text messages whereby the sender can specify the area in which the recipient must reside in order to receive the message, to enable described agent-based session mobility in next-generation network [15].

Agent-enabled Group-Oriented Service Provisioning in Next-Generation Network. Superdistribution [19] is the combined distribution and market scheme for digital goods involving buyers (i.e., end-users) in the distribution process in such a way that they redistribute a good to other legitimate buyers. The principle of superdistribution is tightly connected with the viral marketing phenomenon [14]. Superdistribution can be explicit (end-users exchange digital goods) or implicit (end-users exchange recommendations for digital goods, while digital goods are distributed by businesses that act as content providers (e.g., via *iTunes Store*)).

We implemented a JADE multi-agent system for group-oriented service provisioning in NGN [16][17]. Specialized agents were in charge of: i) user profile management, ii) user profile semantic comparison, iii) SN creation and analysis (i.e., user clustering/classification). As a proof-of-concept we implemented a group-oriented service RESPIRIS (*Recommendation-based Superdistribution of Digital Goods within*

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[3] Viber is an iPhone application that lets users make free phone calls to other iPhone users that have Viber installed (*http://www.viber.com*).

Implicit Social Networks). The innovativeness of the RESPIRIS service lies within the fact that it represents the implicit superdistribution scheme - superdistribution groups (i.e., ahSNs) are generated dynamically and implicitly based on mobile user profiles. Namely, each subscriber of the proposed service is represented by a corresponding profile wherein his/her preferences are described (e.g., what sort of digital good he/she is interested in, of which genre, etc.). User profiles are used for semantic clustering of users into superdistribution groups. The groups users are allocated into are based on users' preferences' similarities and built autonomously.

Possible ahSNS scenario can be the following. If a particular user, e.g., Bob, is interested in the RESPIRIS service then his personal agent UA_{Bob} sends a registration request to the specialized agent on ahSNS server (e.g., RESPIRIS Agent, RA). The RA contains a list of *m* user profiles whose users subscribed to the RESPIRIS service and allocates these profiles into *k* groups according to users' preferences – every group representing one ahSN. In a particular $ahSN_x$ consisting of n ($n < m$) users, the RA informs each of the *n* UAs of all other UAs within that particular ahSN. Now, when Bob purchases some digital content, all other users from the same ahSN are notified. Moreover, UA_{Bob} can provide other UAs from the same ahSN with information about Bob's usage of a purchased digital content (e.g., a frequency of reproducing a newly purchased song) or his level of satisfaction with it (e.g., Bob's explicit rating of a newly purchased song).

Described approach in digital goods distribution ensures that all involved parties benefit from interactions between ad-hoc groups of end-users. Namely, let alone the fact that providing digital goods does not imply almost any production expenses, the content provider need not perform resource-consuming tasks such as advertisement - the advertisement becomes redundant as users receive recommendations from other users in the same ahSN. On the other hand, end-users benefit from this solution as it facilitates choosing from a large number of generally available digital goods, as they are provided with the ability to concentrate on a smaller number of recommended goods. What makes these goods potentially interesting is the fact that recommendations are sent by users from the same ahSN, which is assembled according to the similarity in preferences of users whose profiles it encompasses.

Agent-enabled Collaborative Urban Computing. The main idea behind Collaborative Urban Computing (CUC) [3] is that a set of users, physically located in an urban environment, can serendipitously cooperate using their computing devices (e.g., mobile phones or laptops) to achieve a common goal. The idea of CUC is related to the opportunistic computing paradigm, where different types of devices with networking capabilities represent distributed resources which can be pooled together and used collectively to improve the overall user Quality of Experience (QoE) [6]. We implemented a multi-agent system enabling a proof-of-concept CUC service, which we named the *Collaborative Downloading*. The Collaborative Downloading service replaces today's standard approach to mobile service provisioning (i.e., the individual approach) with the novel collaborative approach. In the individual approach, mobile users communicate only with the content server and download the entire desired content autonomously using certain mobile network technology. On the other hand, the collaborative approach allows mobile users interested in the same content to collaborate and download the desired content together. Content on the content server is divided into several parts and each part can be downloaded independently from the server via certain mobile network technology (e.g., *General Packet Radio Service*, GPRS). After downloading, these parts can be exchanged with other mobile users using an ad-hoc network technology (e.g., Bluetooth).

Possible ahSNS scenario can be the following. If a particular user, e.g., Bob, is interested in the Collaborative Downloading service then his personal agent UA_{Bob} sends a registration request to the specialized agent on the ahSNS server (e.g., Collaborative Download Agent, CDA), Together with the registration, UA_{Bob} authorizes CDA to track Bob's location. Consequently, the CDA contains a list of *m* user profiles whose users subscribed to the Collaborative Downloading service, as well as their current locations. The whole system is on hold until one of the registered users (i.e., Bob) requires a certain downloading service. Now, the CDA firstly filters all registered users according to Bob's current location and then identifies a group of n ($n < m$) users representing Bob's "ahSN for collaborative downloading", who are invited to collaborate (according to rules defined in [2]) while downloading the content Bob is interested in. At the end, computing devices of all users from Bob's "ahSN for collaborative downloading" who agreed to collaborate contain the entire content Bob was interested in.

6 Conclusions and Future Work

Recent technical advancements in computing devices and communication networks changed the way people use Information and Communication Technology (ICT) systems. One of the most obvious examples is rapid proliferation of the social networking services (SNSs) during the last decade. As a result, today there exist a myriad of SNSs, which all support more or less permanent social relationships. However, SNSs will evolve from ego-centric social networking systems into smart community systems by taking into account spatial and temporal information about users, as well as having in mind their specific knowledge/skill/experience/interests.

In this paper, we presented the ad-hoc social network (ahSN) paradigm which supports spontaneous cooperation between a set of users physically located in a limited geographical area during a certain period in time and all sharing a common goal. Furthermore, we described functionalities and architecture of a platform for ad-hoc social networking and gave a brief overview of platform's possible applications.

For future work, we plan to implement a platform for ad-hoc social networking using software agents and extend a list of platform's supplementary services.

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