Online ISSN 1848-3380, Print ISSN 0005-1144
ATKAFF 57(1), 58–65(2016)

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# BeFriend: A Context-Aware Ad-hoc Social Networking Platform

DOI 10.7305/automatika.2016.03.1037
UDK 004.775.031.43.048-045.7:621.395.721.5

**Original scientific paper**

Ad-hoc social networks, focused on managing user social relationships in a novel fashion based on establishment of temporary social connections among users with mutual interests and/or needs, provide an innovative medium for upgrading existing, as well as developing new social relationships. This paper describes the BeFriend, a context-aware ad-hoc social networking platform based on Facebook and Google+ social graphs. The BeFriend platform is for mobile users equipped with a smartphone – after installing and activating the BeFriend client, they are able to receive push notifications when a certain rule is triggered (e.g. it is Friday evening, Ewan and Luke are drinking beer in a bar and one of their Facebook/Google+ friends passes nearby). Personal agents within the BeFriend platform provide autonomous decision-making in the platform, decrease the need for user input and enable automated social discovery of new community members. The proof of-concept BeFriend platform presented in this paper is available in form of BeFriend application for users possessing Android-based smartphones.

**Key words:** Social graph, Social discovery, Facebook, Google+, Ad-hoc social network, Context-awareness, Proximity tracking, Belief-Desire-Intention agents, Autonomous decision making, Multi-agent system

**BeFriend: platforma za kontekstno-svjesno ad-hoc društveno umrežavanje.** Ad-hoc društvene mreže su usmjerene na novi pristup upravljanju društvenim odnosima koji se temelji na uspostavi privremene društvene povezanosti među korisnicima sa zajedničkim interesima i/ili potrebama. Na taj način ad-hoc društvene mreže predstavljaju inovativni medij za nadogradnju postojećih te razvoj novih društvenih odnosa. Ovaj rad opisuje platformu za kontekstno-svjesno ad-hoc društveno umrežavanje BeFriend, koja je zasnovana na društvenim grafovima Facebook i Google+. Platforma BeFriend je namijenjena korisnicima pametnih pokretnih uređaja te omogućuje, nakon instalacije i aktivacije klijenta BeFriend, primanje push-obavijesti potaknuto aktiviranjem određenog pravila (primjerice, Ewan i Luke piju pivu u kafiću u petak navečer te njihov Facebook/Google+ prijatelj upravo prolazi pokraj kafića). Osobni agenti koji su dio platforme BeFriend omogućuju samostalno donošenje odluka unutar platforme, što smanjuje potrebu za korisničkim akcijama ili intervencijama i omogućuje automatski pronalazak novih članova društvene zajednice. Prototip platforme BeFriend koji je opisan u ovome radu dostupan je kao aplikacija BeFriend korisnicima koji posjeduju pametne pokretne uređaje zasnovane na operacijskom sustavu Android.

**Ključne riječi:** društveni graf, pronalazak zasnovan na društvenim vezama, Facebook, Google+, ad-hoc društveno povezivanje, svjesnost o kontekstu, praćenje udaljenosti, agenti zasnovani na paradigmi vjerovanje-želja-namjera, samostalno odlučivanje, višeagentski sustav

## 1 INTRODUCTION

Ad-hoc social networks [1] provide an alternative, temporary and goal-oriented medium for communication and interaction among users. This kind of social networks represents an innovative platform for handling ego-user current social relationships, as well as provides an effective solution for developing new social relationships [2].

For example, imagine a person walking through a city center, available to others for social discovery and interaction. Let us assume this person has few of her friends close by, which is where BeFriend kicks in. *BeFriend* is a context-aware ad-hoc social networking platform which gives its users the ability to receive notifications when their Facebook or Google+ friends pass nearby. Additionally, it enables them to create new social connections. Our person from the story above could, for example, use the BeFriend to get a group discount for shopping in a store which she (and her friends) previously "liked" on Facebook. In practice, this could be proven useful in cities where shorter distance is appropriate for the “same place, same time” principle, enabling social discovery within ad-hoc user groups.

From the research perspective, building an ad-hoc social networking platform raises a very relevant research question of *real-time and dynamic spatio-temporal social community discovery*. On the other hand, there are com-

plex technical challenges connected with big data mining while minimizing user input and taking privacy and security issues into account [3]. Additionally, research studies have been made in the field of implicit social networking [3][4], utilizing and generating user profiles from multi-source data [5] as well as calculating user influence in social networks [6]. The BeFriend platform differentiates from other ad-hoc social networking solutions because it uses the Belief-Desire-Intention (BDI) agent methodology to approach the research problem and JADEX, the BDI framework for Android smartphones, to provide a technical solution [2].

This paper is organized as follows. Section 2 gives an overview of what has already been done in the area of context-aware ad-hoc social networking. After that, Section 3 presents our ad-hoc social networking platform named BeFriend by giving an answer to the question "what does BeFriend do". Afterwards, Sections 4 and 5 give answers to questions "how does BeFriend work" and "what does BeFriend have to offer to end-users". Finally, Section 6 concludes the paper and gives an overview of the planned future work.

## 2 RELATED WORK

Definition of a *context* is given in [7] – "context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves". Therefore, a context-aware system is "a system that uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task".

Mobile users are nowadays accompanied by their mobile devices, usually smartphones. As of late June 2014, the biggest social network Facebook had 1.32 billion active users, out of which more than 80% (1.07 billion) are mobile[1]. Clearly, the ability to go mobile gives social networks an advantage when it comes to usability and popularity among users. In December 2012 the *Facebook Nearby* has been introduced, as a new Facebook service in this area [8]. As of early 2014, popular location based social services are *Foursquare*, *Google Latitude*, *Skout* and *Banjo* just to name a few. These services give the user an opportunity to keep in touch with friends using location-based data.

A newer social networking service similar to BeFriend is *Highlight*, notifying its users of people nearby that they have something in common with. The shift in social discovery approach that made Highlight successful is the fact that it does not require a "check-in", like Facebook or Foursquare does. Instead, it shares information continuously, quietly running in the background and notifying users when necessary – just like BeFriend does. Such ubiquitous and pervasive approach to social networking is necessary in order to accommodate for the fact that closely tied communities often share common places as meeting points, thus increasing chances of triggering social discovery [9]. Additionally, common user behaviour shows that process of adding new friends happens at a faster rate than visiting new locations [10], proving the point further. Social networking service *SocialRadar* in 2014 is converging with ubiquitous, pervasive head-worn computer Google Glass; it uses augmented reality to display social connections on an optical head-mounted display in real-time [11].

[1] http://newsroom.fb.com/Key-Facts

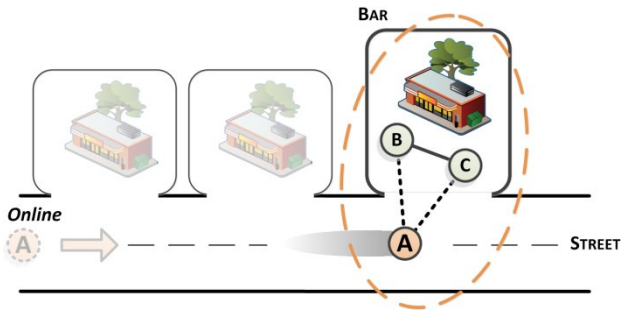


Fig. 1: Social, geo-locational and temporal information as a user context

It is the context-awareness that all services presented in this section have in common; within the BeFriend system it includes (Fig. 1):

- *social context* – i) ego-user's friends; and ii) ego-user's presence information;
- *geo-location context*;
- *temporal context*.

Unique features that BeFriend has to offer are its presence states (see Subsection 4.1) and user-friendly personal agents (see Section 5) that provide autonomous decision-making in the platform, decrease the need for user input and enable social discovery of new community members – all of which leverage BeFriend's potential to serve as a platform for ad-hoc social networking of its users (e.g. see Subsection 4.2).

## 3 BEFRIEND MODEL – SAME PLACE, SAME TIME

When it comes to BeFriend there are two keywords to be aware of – *context-awareness* and *social aspect*. They are described in more detail in the following two subsections.

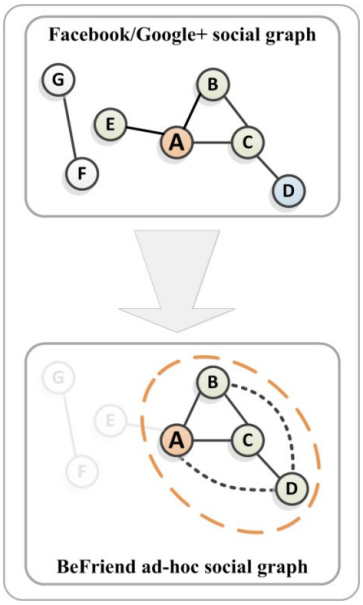


Fig. 2: Social graph translation from Facebook/Google+ to BeFriend

### 3.1 Context-awareness

Context information is necessary and crucial for new social interactions and connections. In Fig. 2 the referent *Person A (Alice)* is cycling down the street, going to meet her *Friend B (Brian)* and *Friend C (Chris)*, who are already at the bar. *Alice* does not know exactly where they are, so she decides to try out her luck. Soon after, if all three of them were *Online* on the BeFriend, they would receive a notification saying that they are close to each other, giving them the ability to meet at the same bar. They could collaborate and, for example, make a video about their favourite beer brand and win a prize. It is all about being in the same place at the same time.

### 3.2 Social aspect

BeFriend model is based on a social graph, which can effectively be used to describe social connections. First, BeFriend uses the Facebook and Google+ graphs as a starting point. In Fig. 2 the referent *Person A (Alice)* is a friend with *Friend B (Brian)* and *Friend C (Chris)* on Facebook. What happens next is that they end up being in the same place at the same time (i.e. context information includes geo-location and time). Ego-user *Alice* is, besides *Brian* and *Chris*, also in company of *Person D (Dana)*. *Dana* is a friend of *Chris* which makes her a friend-of-a-friend for the referent *Alice*. *Alice* and *Dana* talk to each other and find out that their application BeFriend "sees" them as friend-of-a-friend to one another (i.e. social discovery, see Subsection 5.4). The same could be said for *Brian* and *Dana*, as well. This allows them (the pair *Alice-Dana*, as well as the pair *Brian-Dana*) to connect and become friends on Facebook just by being in the same place at the same time, while having mutual friends on Facebook (i.e. *Chris*). Through social discovery, newly established social connections provide great opportunities for collective user activities later on (e.g. watching a movie together or dating).

### 3.3 Privacy preservation and security issues

In mid-2013, *Skout* was informed of potentially devastating privacy vulnerability[2] which enabled anyone to fetch locations of *Skout* users down to street-level precision. For safety reasons, BeFriend does not identify a user's precise location in its notifications to other nearby users; instead, a simple statement „User X is nearby!" is used (Fig. 3(c)).

One would probably seriously question the problem of privacy in location-aware social networking services [12] with 83 million accounts that are alleged spammers on Facebook [13]. In 2015, 25 percent of large global organizations will have appointed chief data officers to manage user data[3] and mobile users will provide personalized data streams to more than 100 apps and services on a daily basis[4]. Clearly, it is of essence to be specific about exactly what information users share, with whom and when, features which Facebook fully enabled in late 2012 [14]. In this regard, the BeFriend system is user-transparent and secure; it allows users to disable their location sharing at any given time (see Subsection 4.1) and utilizes user's relative proximity to others as basis for social discovery – BeFriend does not use a map, address or exact coordinates [2].

## 4 PROOF-OF-CONCEPT FOR BEFRIEND PLATFORM

In order to use the BeFriend platform, one should have an active Facebook or Google+ account, a smartphone with an available Internet connection and the BeFriend application installed [2]. The application is available for Android OS (*Operating System*) and uses on-screen notifications for content delivery. The BeFriend system architecture and implementation are described in detail in [2] and are out of scope of this paper.

### 4.1 BeFriend application for Android OS

Figure 3 presents screenshots of the BeFriend application and its functionalities. After logging in, the user is prompted to allow the BeFriend to access her/his basic information on Facebook or Google+ social network (or both). By allowing access, user gets the following options (Fig. 3(a)):

[2]http://corte.si/posts/security/skout
[3]http://www.gartner.com/newsroom/id/2659215
[4]http://www.gartner.com/newsroom/id/2654115

- view *All friends* list on BeFriend;
- view *Friends Nearby* list on BeFriend;
- view *Friends-of-friends* list on BeFriend;
- view *Friends-of-friends-of-friends* on BeFriend.

The *All Friends* option is not context-aware and thus shows all of the ego-user's friends, i.e. BeFriend and Facebook/Google+ friends (Fig. 3(b)). *Friends Nearby* shows friends within a given distance (the default is 100 meters), which makes it context-aware. *Friends-of-friends* and *Friends-of-friends-of-friends* lists are similar context-aware lists of people that are two and three degrees away from the ego-user, respectively. Ego-user can add new friends from those lists in the BeFriend application easily. Finally, in case the user has one or more friends nearby and has a presence value set to *Online* or *Invisible*, she/he will get notified (Fig. 3(c)). Only friends that are not on the *Ignore List* (i.e. they are not ignored when in the ad-hoc network) are listed in the notification.

There are four presence states supported by BeFriend – *Online*, *Busy*, *Invisible* and *Offline*. These are important to acknowledge as they represent a significant and distinctive feature of the BeFriend system. *Online* makes the user visible to others in the network and available for notifications. *Busy* makes the user visible to others in the network but does not bother the user with notifications. *Invisible* makes the user invisible to others, but makes her/him available for notifications about others. *Offline* indicates the user is not using the application at the moment.

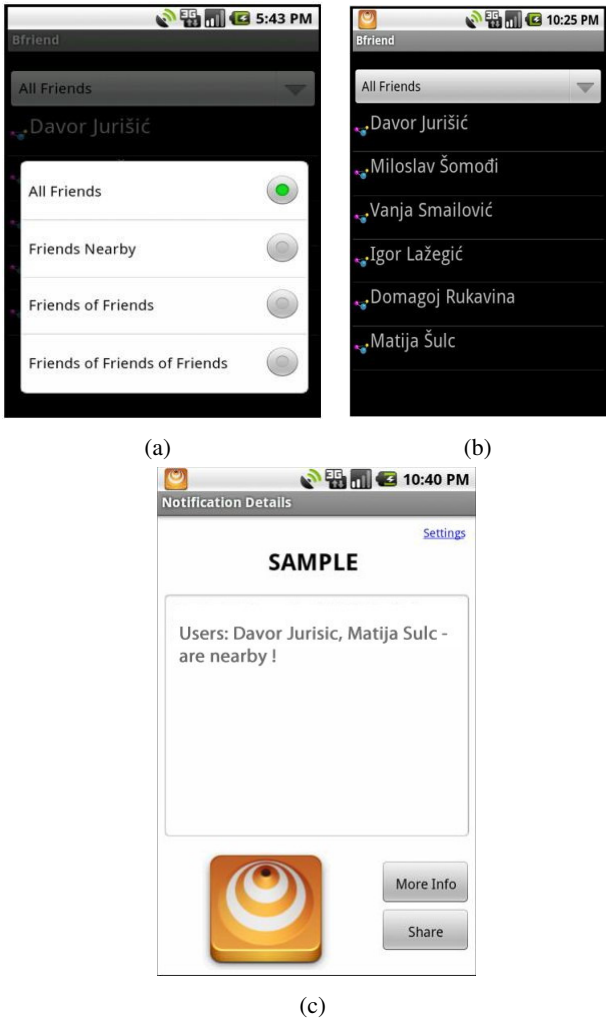


Fig. 3: a) BeFriend application friend lists; b) BeFriend application All Friends list; c) example of a notification alerting about two friends nearby

### 4.2 Common usage and basic functionality

Figure 4 presents a sequence diagram of the scenario in Subsection 3.1, describing BeFriend's basic usage and reveals in what order processes execute. Users *Alice*, *Brian* and *Chris* simultaneously *move around* and their smartphones periodically *send geo-location* to the *BeFriend central server*. Once *Brian* and *Chris* arrive at the bar (X, Y), *Alice* comes close to their location and triggers push notifications to all of them.

### 4.3 Advanced Features

*"Ewan is walking towards the main square to meet his girlfriend. He sets his presence to Invisible, as he does not want to be present in the ad-hoc network of his friends but, nevertheless, wants to be aware of other friends nearby. As he passes by the most famous pub in the city, he receives a group notification saying that five of his friends are close by. On the other hand, his friends did not receive the notification about his proximity as he is invisible in the network. Despite being in a hurry, he decides to drop by just to say hello. On his way out, he quickly checks for friends of friends' names because he did not have much time to remember everybody properly. Maybe he will add them as his direct friends one day."*

This example shows advanced functionalities and features BeFriend has to offer. Ewan is invisible throughout the entire scenario and, eventually, uses "friends-of-friends" feature to find out more about people he just met. Similar scenario would include meeting new people in a disco club during a night out (using friends-of-friends feature) or using some other presence state (e.g. *Busy*) while attending a business meeting.

### 4.4 Dynamic urban scenario – mobile health

*"Ewan is driving in his car when suddenly he receives a BeFriend notification that there has been a traffic accident*

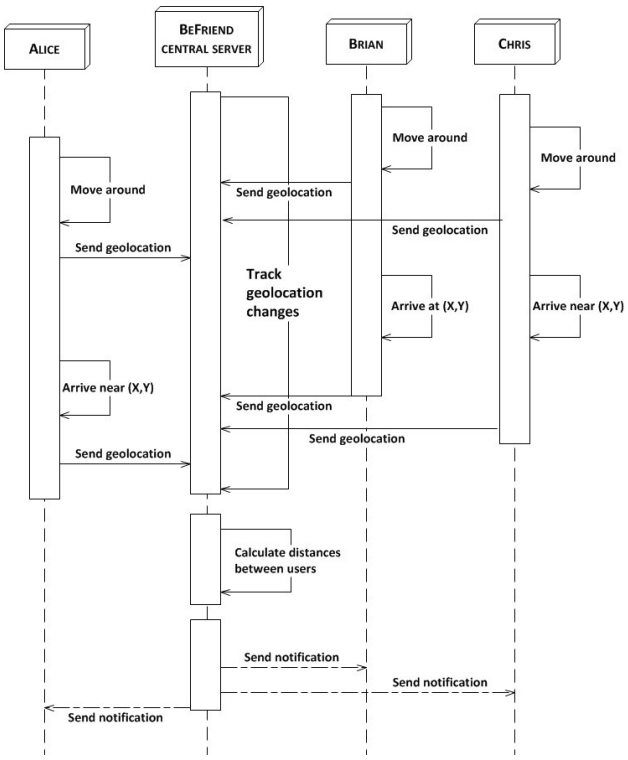


Fig. 4: Sequence diagram showing BeFriend's basic usage

*nearby, involving his friend Luke. At the same time, all other Luke's friends that are nearby and Online receive it too. They figure – Luke could be in a serious danger. They open their chats and agree to proceed to the site to find out that their friend has been injured and is unconscious. The paramedics that issued the notifications are already on their way, so Ewan and friends wait there to help them identify Luke and notice them of any medically relevant information they should be aware of – it could save Luke's life."*

In this example, there has been an accident in which emergency services, such as 112, often need some additional information about injured people involved in the accident. Close friends or family are a great source of such information. The *eCall*[5] is an example of such project, assisting in traffic accidents by providing additional information prior to sending emergency teams or others to help. Additionally, healthcare monitoring represents other application where dynamic collaboration based on social networking is highly relevant [15].

## 5 BELIEF-DESIRE-INTENTION AGENTS IN THE BEFRIEND PLATFORM

*Belief-Desire-Intention* (BDI) agents emerged in late 1980's [16] with a philosophical approach that included analysis of action and reasoning. This approach claims three distinctive phases that every rational agent has: i) *Beliefs*; ii) *Desires*; and iii) *Intentions*. *Beliefs*, in short, are sets of information that make up the "knowledge" an agent has of the current state of world. *Desires* are the motivational drive of an agent – they are made out of desired end states for the given inputs. *Intentions* are simply desires that were, in some point in time, put to action or are in progress.

BeFriend BDI agents provide autonomous decision-making in the client application, decrease the need for user input and enable social discovery of new community members. They are implemented using the *BDI model*. In the next subsections, three BDI agents are presented ($Bond$, $Pythagoras$ and $Leeloo$), providing added value to the BeFriend service [17]. Agents are implemented using the JADEX[6] for Android and deployed on the JADE[7] middleware framework.

### 5.1 User scenario for BeFriend BDI agents

*"Ewan is attending an important business meeting and is currently driving downtown. He is in a very populated area and the BDI agent $Pythagoras$ switches his triggering distance for notifications to only 50 meters. As Ewan arrives, he mutes his smartphone, forgetting to switch his presence from Online to Busy. No need to worry – the BDI agent $Bond$ does it for Ewan, as it knows he has muted his phone and has been in the same place (i.e. at the meeting) for more than an hour. After the meeting, agent $Bond$ changes Ewan's presence to Online again and the BDI agent $Leloo$ offers him to make friends on Facebook with Mark, important business person with whom he shares ten mutual friends."*

This example explains the extended functionalities that BDI agents $Bond$, $Pythagoras$ and $Leeloo$ provide to the BeFriend system and is used for more detailed explanations given in the next three subsections.

### 5.2 BeFriend agent Pythagoras

Agent *Pythagoras* is a BDI personal agent that dynamically adjusts the triggering distance $d$ (i.e. user-perimeter) for triggering notifications to users. It does so based on input data – density of the population at a currently given location of the user. The bigger the density, the smaller the triggering distance $d$.

In the example above, BDI agent *Pythagoras* is aware of user's current location which is in the neighbourhood of *Donji Grad* with a given population density (i.e. *Beliefs*). After calculating the new value for $d$ it sets the triggering

[5]http://ec.europa.eu/digital-agenda/ecall-time-saved-lives-saved

[6]http://jadex-agents.informatik.uni-hamburg.de

[7]http://jade.tilab.com

distance to $d = 57$ meters (Table 1(a)). This value is appropriate for the neighbourhood of *Donji Grad* since it is heavily populated.

Population data for the city of Zagreb serves as the input data[8]. It has a maximum value of 14,955 residents per square kilometre (*Donji Grad* neighbourhood) and a minimum value of 86 residents per square kilometre (*Brezovica* neighbourhood). Neighbourhood borders in terms of exact coordinates ($X$ and $Y$) should be available as well, enabling the agent to know which location is in which neighbourhood (otherwise this data would be useless). With described input data, the agent *Pythagoras* uses a mathematical formula for calculating the triggering distance $d$ as follows:

$$d = \frac{10^5}{\text{density} + 50} + 50, \ \text{density} \geq 0, \qquad (1)$$

where $d$ is the triggering distance (in meters) and *density* is the population density for a given neighbourhood (in residents per square kilometre). Formula (1) is appropriate for the given task since it has:

- a minimum value of $d = 50$ meters ($\text{density} \to \infty$);
- a maximum value of $d = 2,050$ meters ($\text{density} = 0$).

The above means that the triggering distance $d$ ranges between $50$ and $2,050$ meters, which is ideal for software implementation since it reduces the chance of errors by naturally imposing those boundaries without the need for further constraints. Figure 5 shows how the triggering distance $d$ changes for population densities between $0$ and $3,100$ residents per square kilometre.

### 5.3 BeFriend agent Bond

There are four presence states supported by BeFriend – *Online*, *Busy*, *Invisible* and *Offline* (see Subsection 4.1). It would prove useful if the user did not have to change this presence state manually and often. Agent *Bond* is a personal agent in charge of switching the presence state from *Online* to *Busy* whenever either of the two conditions is met:

- the user has her smartphone set to mute (or vibration-only);
- the user has not changed her location for at least an hour (obtained heuristically).

In the example below (Table 1(b)), the BDI agent $Bond$ has realized that the user's smartphone is muted (i.e. *Belief*). Knowing that, the user presence should be set to *Busy*

[8]Croatian Bureau of Statistics: http://goo.gl/rt4JKV

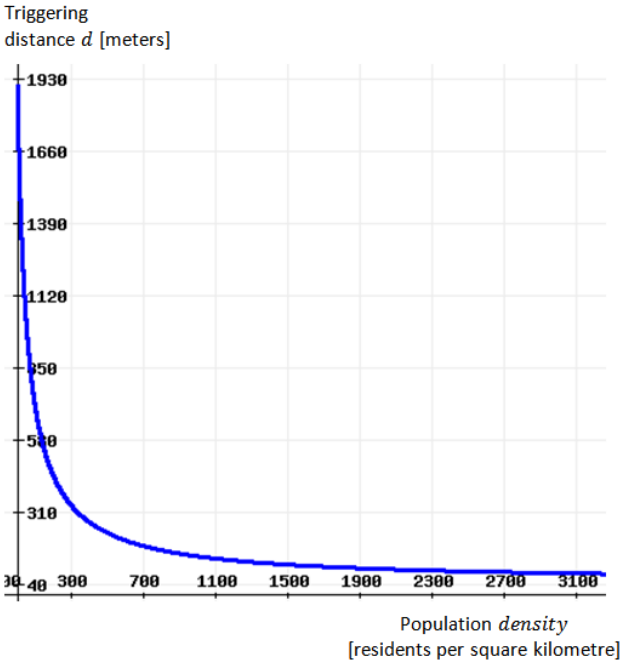


Fig. 5: Graph of the function defined by Formula (1): triggering distance $\boldsymbol{d}$ in relation to population $\boldsymbol{density}$

(i.e. *Desire*), what creates the corresponding *Intention*. This feature is a variation of a well-known pervasive computing problem which requires an extensive understanding of user's context – agent $Bond$ is just one implementation of it [18].

### 5.4 BeFriend agent Leeloo

Agent $Leeloo$ connects the user with available "friends of friends" nearby. It does so by checking the number of Facebook friends in common with available friends of friends near the user; if that number is equal or greater than five and the given friend of a friend is *Online* on BeFriend – *Leeloo* gives the user an option to add that friend of a friend within the BeFriend application. In the example above, Ewan is offered to connect to Mark because the number of mutual friends he has with him is ten. The BDI breakdown for the given scenario is given in Table 1(c).

People, when in a hurry, tend to forget to rely upon their social networks to connect to people they have just met. Afterwards, it might not be easy to recall those persons' names and potential connections among people might be lost forever even if they are well-known friends of friends. Agent *Leeloo* enforces the opportunity for social discovery by making sure people do establish that potential connection.

Table 1: Example of a BDI breakdown for an agent: a) ***Pythagoras***; b) ***Bond***; c) ***Leeloo***

| **agent Pythagoras** | |
|---|---|
| Beliefs | • User's current location shows she is in the neighbourhood of *Donji Grad* in Zagreb<br>• User's current neighbourhood (*Donji Grad*) has a population density of 15,000 residents per square kilometre |
| Desires | • User's triggering distance $d$ should be set according to a specific calculation formula |
| Intentions | • Set the user's triggering distance $d$ to $d = 56.67 \approx 57$ meters |
| **agent Bond** | |
| Beliefs | • User's presence is set to Online<br>• User's smartphone is muted |
| Desires | • User's presence should be set to Busy if the user's smartphone is muted<br>• User's presence should be set to Busy if the user's location has not changed in over an hour<br>• Otherwise, user's presence should be set to Online, unless previously manually set by the user |
| Intentions | • Set the user's presence to Busy |
| **agent Leeloo** | |
| Beliefs | • User's presence is set to Online<br>• Within user-perimeter there are two friends of friends; one of them (Mark) has ten mutual friends with the user<br>• Mark's presence is set to Online |
| Desires | • User should be offered to make friends (on Facebook) with all Online friends of friends within user-perimeter sharing five or more mutual friends<br>• User should be offered to make friends (on Facebook) with an Online friend of a friend within user-perimeter only if there is at least one mutual friend within user-perimeter as well |
| Intentions | Offer the user an option to add Mark as a friend on Facebook |

## 6 CONCLUSION

Advances in ICT (*Information and Communication Technology*) during the last decade have enabled telecom operators and other providers to go mobile with a wide range of services and social networking services are not an exception. Context-awareness, such as being able to pinpoint the user geographically or know whether she is at work, in school or just shopping downtown, is critical for dynamic, goal-oriented and temporal approach that ad-hoc social networks assume. Users are no longer satisfied just with "being connected", they need their PC's, laptops and smartphones to be aware of where, when or how they are connected.

The BeFriend platform makes use of those facts by making them the core user requirements of the service – users create, maintain and end their own, temporary ad-hoc social networks using spatial proximity with their friends as a context information. Moreover, context-aware cooperation of personal agents based on the Belief-Desire-Intention (BDI) model adequately tackles dynamics and complexity of the ad-hoc social networks. It provides autonomous decision-making in the client application, decreases the need for user input and enables a novel approach to social discovery of new community members.

Future work will include adding more features to the BeFriend service, such as implementing a chat service available to users within the ad-hoc network, adding a personalization layer on top of the service (making the experience more personal for the user), raising context-awareness in terms of a part of a day (i.e. day or night) or giving users the ability to sign-in with different social network accounts (such as LinkedIn).

## ACKNOWLEDGMENT

The authors acknowledge support of the research projects "Managing Trust and Coordinating Interactions in Smart Networks of People, Machines and Organizations", funded by the Croatian Science Foundation under the project UIP-11-2013-8813; "Ericsson Context-Aware Social Networking for Mobile Media", funded by the Unity through Knowledge Fund; and "A Platform for Context-aware Social Networking of Mobile Users (SmartSocial)", funded by the Ericsson Nikola Tesla company. Additionally, authors are very grateful to Igor Hevcuk, Robert Mrkonjic, Bernard Cosic, Ivan Macinkovic and Ivan Vuk for helping with the implementation of a proof-of-concept system.

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Received: 2014-10-05
Accepted: 2016-03-25