Extending Internet-Enabled Social Networks

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Abstract — **Social networks are already part of our life. These supporting applications ease and promote the social interactions with members of our online communities; e.g. family, friends or colleagues. Provided the advances of the mobile telephony systems, the Social Networking Sites have developed services to be accessed from cellular phones. These services propose an interaction paradigm among social network members that is similar to the one embedded in any Internet-enabled social network, such as Facebook or Twitter. Although such paradigm is useful, it does not take full advantage of the users' mobility or physical location. This article proposes a new and complementary interaction paradigm for mobile members of social networks. This paradigm is based on the physical proximity of members and it promotes face-to-face encounters among them. This interaction concept is supported by a MANET-Enabled Social Network, which extends the currently used Internet-based interaction paradigm. This proposal allows users to address an interaction scenario that is not considered by the current Social Networking Sites.**

Keywords – Social networks, mobile computing, MANET-enabled social networks, interaction paradigm, online communities, face-to-face interaction.

I. INTRODUCTION

New communication technologies are supporting and enhancing the users experiences when they participate in online communities. Internet-Enabled Social Networks (IESN), such as Facebook, MySpace or Twitter allow members to connect and interact with others who have different beliefs or backgrounds, thus increasing their social activities with other people [6]. These systems also make deeper their relations with known groups, such as friends, coworkers or relatives, reinforcing and strengthening existing social ties [5]. The IESN are centralized systems that use Internet as the communication support.

The current use of IESN confirms once again that computer-mediated communication is an interesting support to perform social interactions. Therefore every day more and richer services are added to the IESN. Moreover, a wide range of interaction dimensions is also being defined and used in order to offer IESN members a set of enriched and powerful functionalities.

Social networks are strongly based on the importance of the relationships among the participating people. The relations and interactions specified by the linkages among members trigger users' activities that can be observed as an interdependent process [4].

Advances in the mobile telephony systems have promoted the migration of IESN services towards the mobile phones. Today it is possible to use almost any social network through one of these devices.

The interaction paradigm used by members of an online community when accessing an IESN through their mobile phone is almost the same, independently if they are using a desktop computer, a laptop or a mobile phone. Although this Internet-based interaction paradigm has shown to be useful, even when using mobile phones, it does not take advantage of the users' physical locations and the users' mobility. The reason is very simple; the interaction paradigm proposed by the current IESN does not require taking into consideration these issues.

This paper proposes to extend such interaction paradigm and carry it towards a physical scenario. This extension would allow social networks not only to promote Internet–based interactions among members, but also face-to-face communication instances. For example, let us suppose that two friends, both members of a certain online community, need to talk to each other to deal with a situation. Both are located in the same area at the same time (e.g. a shopping mall), but they are not able to see each other. Most probable result is that they lose the opportunity to address the problem or just to share a cup of coffee. Although both friends are members of the same online community and they have a smartphone able to notify them about physical presence of each other, such interaction opportunity is lost.

The extension of the current IESN interaction paradigm takes advantage of the information about the physical location of social network members in order to promote face-to-face encounters among them. Accessing such functionality does not necessarily require that mobile users have Internet access, because the communication support is provided by a Mobile Ad hoc Network (MANET) [27] and the social network information is kept locally in each device. For that reason we have named such infrastructure as MANET-Enabled Social Network (MESN).

Next section reviews the Internet-Enabled Social Networks and their main features. Section III describes the MANET-Enabled Social Networks and it shows some application scenarios. Section IV describes the MESN main interaction domains. Section V presents the architecture of a hybrid interaction space, which includes a generic architecture for a MESN. Finally, Section VI presents the conclusions and future work.

II. Internet-Enabled Social Networks

Social networks involve users who share similar interests and practices, and who interact regularly over a common communication medium [16, 17]. These networks are composed by nodes (i.e. members) and links that are represented by the interactions among them. The graph representing a social network is the basis to promote and support the social activities of a community [4].

We refer as Internet-Enabled Social Networks (IESN) to social networking sites that are accessible through Internet; for example Facebook, MySpace, YouTube and Twitter. This kind of sites are attracting millions of users worldwide, enhancing their social life. Depending on the original purpose of these networks, they can be classified as friends, professional contacts or real-time social networks. Next sections explain the main features of each category.

1) *Friends Social Networks*

This type of IESN supports informal social relations by allowing sharing personal content and personal/group communications. Some of the well-known friends social networks are Facebook [7], MySpace [9] and Orkut [10]. They provide a similar core of services to their users, for example Facebook's news feed and MySpace's bulletins for social relations awareness; Facebook's Photos and Video applications, MySpace's MySpaceTV and Orkut's integration with Youtube and Google Video, for personal content sharing; and Facebook's Chat and Messages, MySpace's MySpaceIM and Orkut's Gmail for messaging.

These networks provide a full experience according to the design intended by their owners [18]. These IESN have also lightweight versions of their services, which can be used in smartphones if the users have Internet access. Although these lightweight versions provide a limited access to the IESN services, such functionality is enough to cover the main users' needs. For example, it provides users' activity awareness, content sharing and support for interactions among members. Many of these services are also available for software developers through an Application Programming Interface (API). It allows developers to reuse already implemented social networking services and also the data stored in the IESN [19]. Thus, developers can create their own software applications and take advantages of these services.

2) *Contacts Social Networks*

Contact social networks are focused on creating, maintaining and promoting professional links among the community members. Typically each person and company is able to create and maintain a professional profile. Then, other registered users can look for information in such network, and eventually to contact somebody for a professional service or relationship. Some of the well-known contact social networks are LinkedIn [11], ResearchGATE [12] and deviantART [13]. These IESN typically provide support for sharing and discovering professional content, and the services they provide to reach these goals are quite similar among most contact social networks. In LinkedIn such functionality is available through the professional networking services, in ResearchGATE through the scientific research inspired functionalities and in deviantART through the illustrations sharing and discovery services.

LinkedIn services allow for example, searching people and companies filtering by professional information, getting introduced to someone they trust on business and collaborate on several thematic groups, sharing knowledge, exchanging recommendations, and seeking/posting job offers.

ResearchGATE provides functionalities quite similar to LinkedIn. However, ResearchGATE is more specific, therefore it can further expand the discovery features by implementing semantic search capabilities on users' profiles and shared files.

DeviantART provides just a minimal set of social networking services and it focuses on an easy-navigation of the art work and illustrations the users share. Its key features are centered on interacting with those illustrations in a meaningful way. Similar to Friends Social Networks, most of these services are also available in the lightweight version of the Contact Social Networks.

3) *Real-time Information Networks*

Real-time information networks are tools specialized in information sharing and scalable content discovery. Some of these well-known IESN are Twitter [8], Foursquare [14] and Tumblr [15]. Twitter is a "microblogging" service, which allows users to share small pieces of text and hyperlinks (i.e. *tweets*) through different third parties applications. Users can follow other users' activities through the tweets without requiring a mutual relationship between them. Since Twitter has a public Application Programming Interface (API), several applications can reuse its services and take advantage of their data and communication links.

Foursquare is a location based social networking service. It was designed specifically to be used on mobile devices. Foursquare users can perform "check ins" in different places called "venues", share tips with friends and other users, and connect accounts with other platforms, such as Facebook or Twitter. However, the users' location reference is based on the information the users declare, which has three main problems: (1) if a user want to be contacted, s/he must be aware to record such information in the Foursquare site, (2) the user must be aware of the system because the application is not going to notify him/her when a community member is physically close (according to the information in the system), and (3) the location information that supports the interactions among the community members could be accidentally or intentionally wrong or outdated.

Tumblr is also a microblogging site that allows users to share several resources, such as text documents, images, videos, and links. There is not an intrinsic limit on the content type and size of the shared resource. Users can follow other users' activities and interact in several ways with the content that community members share. Similar to the previously described IESN, users can also link their accounts with other platforms through an API.

III. MANET-Enabled Social Networks

Face-to-face interactions are crucial to keep long-term relationships [21], develop trust among online community members [23] and improve the mental health of the people [22]. The authors propose to extend the interaction paradigm of the existing IESN in order to promote face-to-face interactions among members of an online community. Thus a social network could be perceived as a hybrid interaction space composed of a virtual and a physical space (Fig. 1). People are able to use such hybrid space to interact with other members of the online community. Interactions into the virtual space, i.e. among users connected to the IESN, are supported by Internet and the IESN server as today does. Interactions into the physical world, i.e. face-to-face communication instances, are supported by the MANET-Enabled Social Network (MESN). This supporting infrastructure involves a MANET [27] and supporting information of the social network, which is stored into the devices of the community members. Each community member keeps locally its own information of the social networks s/he belongs to; e.g. group membership, list of group members, relationships and privacy profiles. Therefore, the physical interactions support does not require access to Internet or an IESN server.

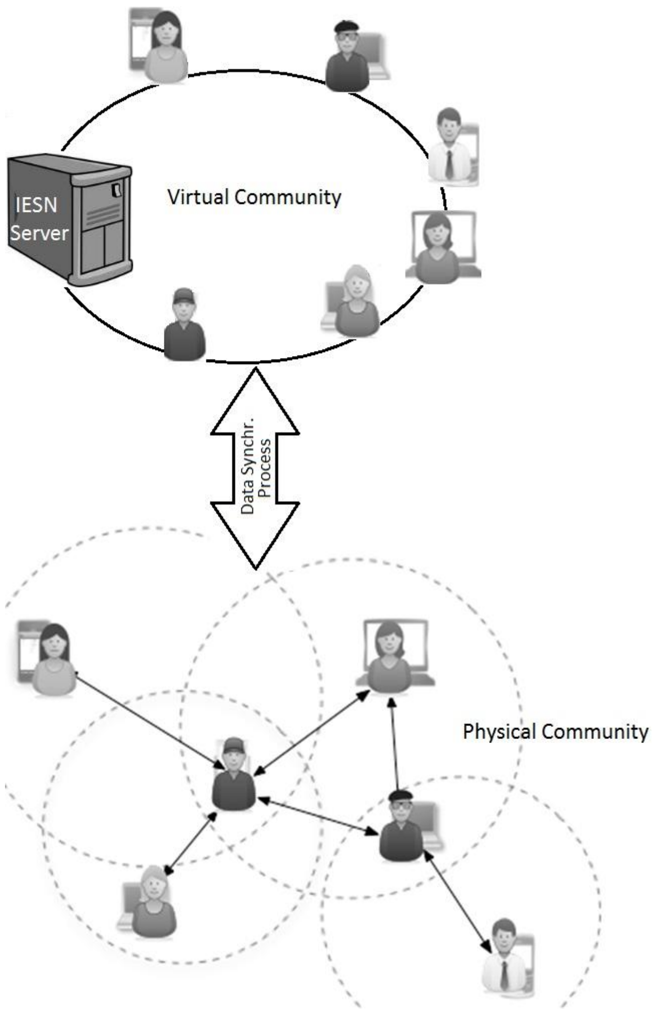

Figure 1. Hybrid interaction space that supports the online community activities

A full-duplex data synchronization process is used to connect both interaction scenarios (Fig. 1). The data synchronization is performed through an on-demand process that runs on the mobile devices of each community member. Such process interacts with the IESN server through the API these social networks typically provide to exchange information with the external applications [19].

When a community member decides to logoff from the IESN because, e.g., s/he is going shopping or to take lunch, s/he downloads to the mobile phone his/her social network contacts from the IESN server. Such information will allow him/her to eventually interact with their contacts in a physical scenario.

Depending on the current setting of the mobile user privacy profile, such user can be *visible* or *invisible* for other community members. If the user is visible and other community member is physically close; i.e. the mobile phones of these users are able to communicate each other directly or indirectly, an alarm message will be deployed on the devices screen. Once received the notification, the users decide if they want to interact face-to-face, by phone or just continue performing the current activity. If a user decides to contact to the other one in order to start a face-to-face interaction, s/he can use a GPS service or an Indoor Positioning System to locate such person. Depending on the physical scenario and the number of people using this system, the ad hoc users detection service could identify people located to a distance between 20 and 150 meters.

Mobile ad hoc networks supporting the interaction process in the physical space have shown to be reliable and useful in circumstances where communication infrastructure is not always available [26]. This communication meshes can implement routing protocols and thus extend their coverage area. This communication service and the rest of the functionality that is part of a MESN are presented in the next sections.

A. Profile Consolidation and IESN Synchronization

In order to synchronize the actions of users when using a MANET as their communication platform, MESN must consolidate all social profiles the user may have. All his/her information is downloaded from the IESNs, consolidated and stored locally in the user device. This information is then propagated through the emergent MANET in order to introduce the users to the ad hoc community (i.e. the physical community).

When the mobile device is able to re-connect to an IESN, the application has the chance to upload all new data recorded as a consequence of the users' actions on the MESN. Such uploading process is in fact a data synchronization process. As a result the IESN will count on the native information and also with those generated through the users' interactions in the MESN.

B. Users Detection and Network Links

Users detection is a key feature that is able to generate alarms in order to give awareness to users about the presence of known people. The awareness of surrounding people indicates how far is a possible contact (in term of number of communication hops), and thus it enhances the chance of creating face-to-face encounters. The feature also enables new linkages between two users that may be in the same place, sharing certain interests.

Most MANET systems allow creating group's meshes where users identify the nodes by a name or other credential elements. This identification process allows devices to recognize when another known user, included in the linkage list, is connected to the network and also physically close.

C. User Status and Location

The user status is a regular awareness service in IESNs, which typically requires the user intervention to change from one status to other. However, in mobile scenarios, the user status is a component that may be automatically set in terms of context location. If a user moves (changing his location) or if the context of the user location changes, the user status automatically will changes and become more dynamic. Applications can setup and share information about known locations to easy the process of context recognition.

D. Positioning System

Outdoor positioning is a feature usually available through GPS or GPSR services in mobile devices. Using such service the user can estimate his location and have awareness about the position of the surrounding linkages.

Indoor positioning systems (IPS) are similar to GPS but they work for indoor environments. Counting on an IPS is highly important for a MESN, because it really eases the search for users into a physical scenario. When a user detects the presence of a community member (e.g. a friend) in the physical space surrounding him/her, the IPS tell him/her in which direction to move in order to do a physical contact with such person. An IPS particularly designed to cover such functionality was proposed by Vera et al. [20].

E. Messages and Gossips

Users are able to communicate between them using the functionalities provided by their mobile devices; e.g. text, voice and video. However, the users mobility and dispersion creates dynamic networks that are automatically split and unified in short time periods. For that reason, the messages exchange not always can happen in a synchronous way. For interaction situations requiring asynchronous communication, other type of messages can be broadcasted using the intermediary mobile devices as carriers. Such messages were named *gossips* and they are propagated taking advantage of the users mobility, whom help propagate the social gossip messages into different networks.

F. Content Sharing

Users connected to a stable network or located close enough to ensure a stable interaction among their devices, are able to share files or social multimedia content via file transfer. They can also comment this content, modify parts of it and thus enrich the shared information. Other strategy to share content, which also requires file transfer support, is data synchronization. Instead of replace resources, this method integrates them. Thus the user can feed his/her information space in an incremental way. This service is used to support the information exchange between the IESN and the MESN.

G. Context Awareness

Since users move through a physical scenario that can be large and diverse, they expect the mobile application behave as context-aware. Depending on the contextual information, such as current time and user location, presence of other users and services, or just the absence of them, can make the application triggers particular services to support the user activities in such particular situation. When the context scenario changes, the application self-adapt in order to provide the user a set of services suitable for the new context scenario. Managing context is an important feature for mobile applications supported by MESNs.

H. Content Discovery

When moving between different places or groups, users can discover new content that enriches the given scenario. It can be perceived by the users as an augmented reality service [28], which allows applications to discover relevant content from peers or physical environment, depending on the time and location where the person use it.

IV. MESN Interaction Domains

Considering the interaction dimensions supported by a MESN and the authors experience as developers of similar mobile applications, we realize these ad hoc social networks can support three types of interaction situations: Impromptu Communication, Topic-Centered Meetings and Multi-Location Simultaneous Events. Next sections explain each interaction situation and show how a MESN could support the activities performed by the mobile users in such scenarios.

A. Impromptu Communication

This interaction domain represents casual (non-scheduled) social/work interactions. Examples of these situations are a casual encounter of two physicians into a hospital or two friends at the street. This interaction situation is also present when a mobile user decides to interact with other one because this last person is now physically close. The authors have developed several mobile collaborative applications (MCA) that support impromptu communication, but they are still not connected to a formal IESN. Some of these applications are the following ones: MeetU [3], extended modules of MobileMap [24] and Coin [25]. All of them use HLMP API [2] because it automatically creates, deploys and maintain a MANET formed by devices that are physically close. In addition, HLMP API is able to deal with the users' mobility, therefore it is suitable to support the activities performed through a MCA or a MESN.

MeetU is a MCA that runs on tablet PCs and cellular phones, and it supports physicians, nurses and medical interns during the hospital work. This application embeds very simple social network services, which were particularly designed to support medical interns' activities. MeetU incorporates some pervasive services, such as a users positioning system, users awareness and users activity estimation. The system allows community members to communicate with each other, set status messages according to the activity estimation and location, propagate gossip messages, and share content related to the work they are performing.

MobileMap and Coin are MCA designed to deal with specific mobile activities. In the first case, the MCA supports the work performed by firefighters attending emergency situations. In the second case the application supports construction inspectors' activities when they are on the move at construction sites. The extensions of these applications, which use social network services, create an additional informal ad-hoc interaction space that supports daily non-critical activities.

The characteristics of these systems deal with the practical difficulties of deploying a fixed communication infrastructure. The users location awareness allows community members to track resources and increase the possibilities of have face-to-face interactions.

B. Topic-Centered Meetings

These meetings are scheduled events, previously coordinated by an external entity or IESN, e.g. a scientific conference, an exposition or business meeting. In these situations the people are collocated (it could be in a classroom or into a small area) and take advantage of such situation to generate social interactions among them. Examples of MESN-based applications that can support social interactions among community members in topic-centered meetings are the following ones: ReLink (Researchers Linker) and MUTopics (mobile academy courses).

ReLink is an application, currently under development, that expands the social enabled experience of the people participating in a scientific conference. The application uses a MESN to consolidate the profile of the conference attendees, and also to coordinate the social content. Using information about the attendees' physical location and scheduled social activities of the conference, ReLink offers an alternative social network that triggers interaction possibilities among researchers. For example if two or more researchers that share the same research area are physically close, the system is going to notify them.

ReLink also manages research linkages. Using Internet information services, such as Google Scholar, the system detect citations to articles of the current user. If one author cites another author's work, the system will create a unidirectional linkage between them. All this information (including social information, conference proceedings, scheduled activities and locations maps) is jointly pre-loaded into the mobile application before the meeting. Such functionality is provided by the ReLink preloading service.

During the conference, ReLink detects when users related to a linked group are around, and then it reports the users' location into a map deployed in the mobile device. People having the same research interests, can meet face-to-face, share experience and plan future joint work. When attending presentations, users are also able to comment, submit questions or share information related to the current presentation.

The second MESN that supports Topic-Centered meetings is MUTopics. It is a mobile system designed to be used by students and instructors in an academic environment. Typically the universities have content management system (CMS) that address the needs of students and the academic staff involved into a course. Such CMS has, e.g. the list of persons participating in the course, and also the shared information for the participant. MUTopics is a collaborative mobile application that creates a MESN using the information of a course members list, which is consumed from a CMS.

The system also allows course members to communicate, download/upload subject's content, and manage formal information. This data can be synchronized later with the CMS, however social information, as linkages are kept locally in the users' device. When course members move around campus, and particularly when the MANET emerges, people can activate the MUTopics application in order to detect classmates, ask for new classes' location, share content and schedule face-to-face interactions with other students/instructors.

C. Multi-Location Simultaneous Events

This interaction scenario extends the topic-centered meetings. The multi-location simultaneous events are scheduled and large events that may be happening at the same time in various locations; e.g. the Soccer World Cup, the Olympic Games, government elections or holydays parties (e.g. Christmas, New Year or Halloween parties). This interaction scenario considers two stages: anticipation sessions of the event and the interaction sessions during the event.

The anticipation sessions are typically performed through an IESN. For example, members of a Facebook community that are anticipating the Soccer World Cup – Brazil 2014, can interact to create a social context for the tournament dates. The anticipation includes teams players and expectations, statistics about past tournaments, bet systems, comments and information sharing about the different stadiums and touristic locations. When the dates of the tournament are close, the MESN-based application preloads all the context and social information into the mobile system.

Let us suppose that some of the community members decide to go to the stadium to see a soccer match. When the MANET emerges at the stadium, these people can detect other community members in the same place and eventually join or contact them. Community members, whom are fans of different participating teams, can also interact and make jokes to each other while they are collocated into the stadium. This feature extends the sport-game itself and generates a social real-time interaction. Users can share emotions according to the course of the game.

At some point, when an user have access to an Internet spot, he can synchronize all his social information with the IESN, in order to give awareness to other community members about the social activities carried out at such stadium. This information is useful to trigger interactions with other community members whom are located in other stadiums or at home watching the soccer match.

Figure 2 uses the categories defined for Internet-Enabled Social Networks (IESN) in order to present a domain classification of social networks. The classification considers the interaction paradigms analyzed in this article, i.e. server-centered paradigm used by the IESNs and the ad hoc mobile paradigm used by the MESNs. Figure 2 also shows how to map the products and examples mentioned in the Sections II and IV, to the categories obtained from this classification.

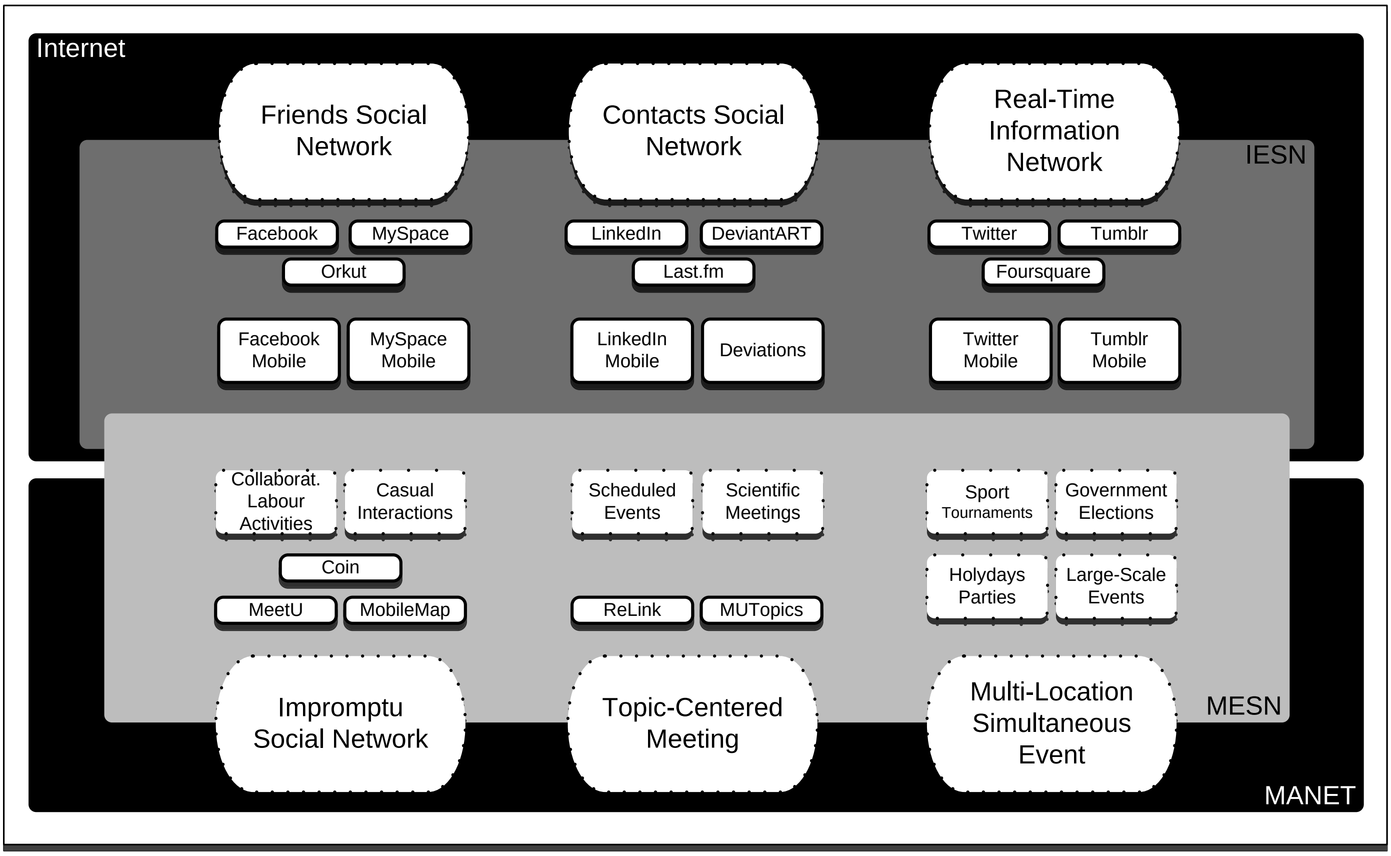

Figure 2. Domain Classification of Social Networks

V. The Architecture of a Hybrid Interaction Space

The development of mobile collaborative applications has been identified as an important challenge, and the main reasons are two. On the one hand, the users mobility and the communication instability that is present in mobile wireless networks render centralized components (e.g. a server) useless, because it is not possible to ensure the access to such resource when the mobile user requires it [29].

On the other hand, most functionalities required by users to perform mobile activities and collaborate on-demand, are not visible to software developers. Such situation has been named as the iceberg effect [30], and it means that just the functionality deployed in the application user interface become relevant for software designers.

These two reasons indicate that mobile collaborative applications, e.g. a MESN, must count on a reference architecture that helps software designers to identify the components that are behind the user interface. Figure 3 presents a reference architecture for a hybrid interaction space which considers the interaction between the virtual and the physical community.

The virtual space, i.e. the IESN and the services used to interact in such scenario, is the one used today by people around the world. These virtual spaces provide an API that allows to an external software application (e.g. a MESN) to interact with it in order to access public services and data [19]. Since each API is different depending of the resources source, the MESN considers an IESN communication layer composed of several controllers; each of them is specifically designed to interact with a particular IESN (e.g. Facebook).

An events manager acts as intermediary between the IESN controllers and the MESN services. Typically it manages the input/output of services invocations, providing thus a unique interface with the IESN, other mobile nodes, and also any external application that want to collaborate on-demand.

The MESN main services are grouped in four categories: social information, supporting services, user interface and communication system. The *communication system* must deal with several and well-know challenges, such as to provide ad hoc message exchange among nodes deployed in the physical scenario, automatically form a MANET, and maintain a dynamic network topology [1]. The authors have been involved in the design and implementation of one of these communication infrastructures, which have been used to support several ad hoc mobile collaborative applications [2]. Therefore, this component could be reused from the authors' previous work.

The *user interface* must expose, through the graphical user interface, the services and awareness mechanisms required to perform each particular activity. Depending on the type of interaction to be supported, a specific user interface should be designed for such mobile application.

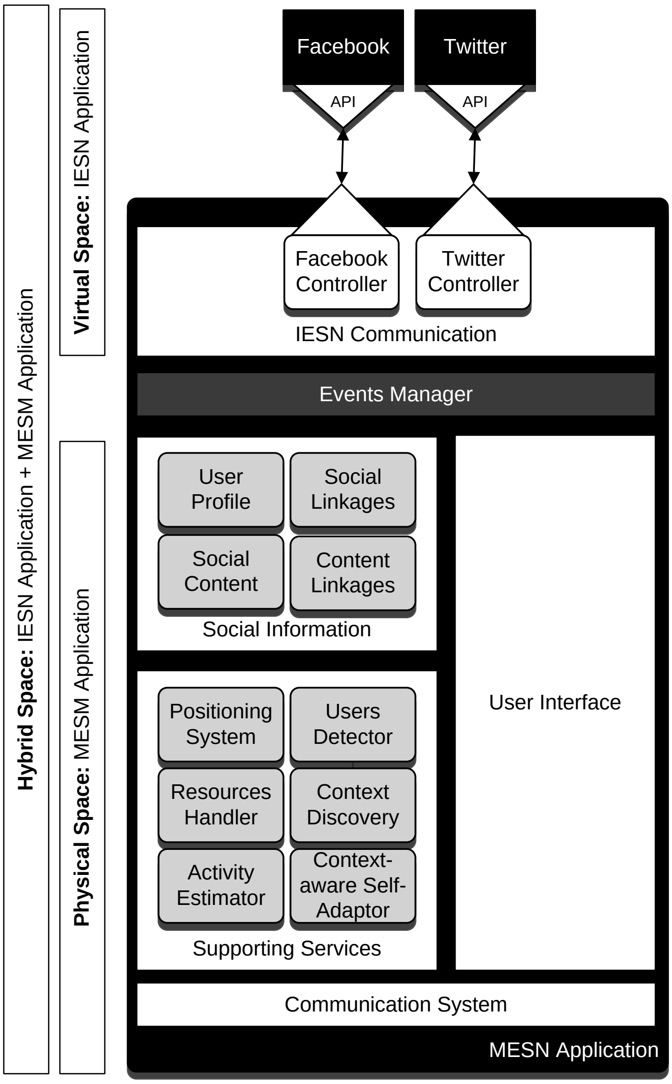

Figure 3. Architecture of a hybrid interaction space

The *supporting services* perform specific functions that are used by other services to expose complex and rich functionality to the users. This component involves six services: a context discovery, a context-aware self-adaptor, an activity estimator, a resources handler, a users detector and a users positioning system. Several of these components are already part of the coordination services embedded in HLMP API [2]. The context discovery is responsible to identify and notify context changes to other MESN services, and also to record and retrieve context variables. The context-aware self-adaptor is in charge of self-adapt the mobile application when the context environment changes considerably; e.g. when a mobile user gets isolated. The activity estimator infers the type of activity being performed by a mobile user, and based on such information it deploys on the user interface the services that could be required by the user. The resources handler is responsible to manage the private and shared resources of each mobile node. The users detector informs, through an awareness component, when a particular mobile user is available or not for interactions, and also informs the connection status of all MANET members. The users positioning system is an IPS that helps to find a mobile user into a physical scenario. The authors have developed an IPS named EDIPS (Easy to Deploy Indoor Positioning System) [20], which have been used to locate nurses and medical interns in a hospital.

The social information component involves four services: User profile, social linkages, social content and content linkages. The user profile service allows creating and maintaining the profile of a user, including privacy issues. The social linkages service maintains the social links among users and also provides such information to other MESN services. The social content and content linkages manage interrelated information that a user wants to share with others community members.

The services deployed in this architecture play a key role into a MESN, by allowing the users interactions in the physical space. This architecture should help software designers to address the challenge of modeling a MESN.

VI. Conclusions and Future Work

This article introduces the MANET-Enabled Social Network, which extends the current interaction paradigm implemented by the Internet-Enable Social Networks such as Facebook, MySpace or Twitter. The interconnection between these two interaction spaces provides to the users a hybrid scenario where they can collaborate.

Collaboration through the physical space is a completely new concept for social networks and it involves a novel interaction paradigm. It considers that people participating into IESN become able, through the use of a MESN running into a mobile device, to interact with other community members when they are on the move. Thus, it is possible to increase the number of face-to-face interactions among members of a community, which helps to keep long-term relationships [21], develop trust among online community members [23] and improve the mental health of the people [22].

After a first analysis we have concluded that (at least) three general interaction domains can be supported by MESN-based applications: impromptu communication, topic-centered meetings and multi-location simultaneous events. It opens an opportunity to support a broad range of social computing applications.

The article also proposes a reference architecture that helps software developers to address the challenge to model the Hybrid Social Interaction Space; and particularly a MESN-based application. Most components that are part of the MESM application have already been designed, implemented and used by the authors to address specific problems of mobile collaborative applications. Therefore, the effort of implementing a MESN-based system can be reduced considerably through the reuse of these components.

There are two important issues that are still not addressed in this proposal: interactions security and information privacy. This is part of the work the authors are going to address in the next future.

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