Distributed Smart Spaces M3 Platform for Building Professional Social Networks with Seamless PCs and Mobile Access

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Abstract — this paper proposes the social network solution that has been designed to fit equally well for use at mobile devices, PCs and even other types of consumer electronics. This solution is targeted to become a core element of the personal knowledge space and the design has be been done on top of M3 smart space. Target of this paper is to improve and to expand the understanding of the Smart Spaces concept by the R&D community. Through the identification of key properties based on an analysis of evolving trends brought to us by the great convergence in the ICT industry. Based on that we show how this trend will affect adoption of Smart Spaces. It is especially important to understand how Smart Spaces can change the whole services ecosystem and the role that mobile and other types of user surrounding devices will play. The Smart Space concept can be described as a permanent robust infrastructure to store and retrieve information of various types from a broad spectrum of different environment participants. This concept can provide better user experience by allowing a user to bring flexibly to the new devices and access all the information in the multi device system from any device. Based on that the resulting social network solution will be able to pre- and post-process the collected information and perform efficient reasoning over and organization of the data. Another key advantage of the proposed social network is that it is primary targeted to support professional social communications within a geo-distributed teams working on the same project. For that the solution proposes a flexible and easily extendable set of additional services, such as a variety of conference call and virtual meeting services with logging service, sharable whiteboard, automatic maintenance of action point lists and calendars and so on. As a result the service provides users with completely new experience.

Keywords-social networks for mobile devices, smart spaces; M3; supporting distributed R&D projects.

I. Introduction

This paper is based on the conference paper presented at Ubicomm 2009 conference [1]. Social networks are attracting more and more Internet users and soon the absolute majority of the Internet users will have a membership at least in one social network and so social networks become the most demanded type of service in the Internet. Also we have to take into account that in Japan already in 2005 the number of mobile users exceeded PC connections [2] and starting from second half of 2008, the world-wide number of new users connected to Internet through mobile devices is growing faster than users with a classical access from the PCs. This creates a strong demand for a social network solution that equally well fits for use from PCs and mobile devices.

At the same time the new information age mandates development of a permanent robust infrastructure to store and retrieve information of various types from a broad spectrum of different network participants. The environments that fulfill such requirement are called "smart spaces" and assume presence of a number of devices that use shared view of the resources and services. The smart spaces can provide better user experience by allowing a user to bring flexibly to the new devices and access all the information in the multi device system from any device. The challenge of providing consistent information in a smart space is that the resources are distributed over several physical devices and the information consumption is not always happening at the same device where the information is located.

Recently we observed an emergence of the smart space technologies, which are truly mobile by the definition of their nature and allow equally efficient design of applications for PC and mobile devices. An example of such smart spaces platform is Multipart, Multidevice and Multivendor (M3) platform [3][4][5], which has been developed by a consortium of companies lead by Nokia. It gives the user a great flexibility in design and easy to use tools for personalizing the user account and access application as much as user wants. We believe that by designing social network platform on top of M3 we will provide a user with the new truly mobile social network experience and allow integration of social network's information flow with other information flows going via the mobile device and PCs of the user, while keeping all personal data under full physical control of the owner.

Despite a huge number of mobile Internet users, nowadays there is no widely known social network solution that has been specifically designed for mobile use. So when nowadays the mobile user wants to be socially networked he/she cannot get this service or in the best case is forced to use the PC client adopted for mobile device. As a consequence this creates a lot of problems and inconveniences for the user.

The most visible problem is inefficient User Interface (UI), which is usually the scaled down version of PC client UI with some functional cuts comparing to the PC version.

Moreover this UI cannot take into account personal preferences and restrictions of the user and as a result most social network users use the mobile client rarely and only when they do not have other alternatives, which definitely is an unacceptable situation. It would be great if the user gets a possibility to easily build personalized client UI out of the provided library of blocks and when needed easily to make even completely new blocks or blocks with the inherited functionality.

Some other key problems are placed deeply in the architectural principles of the currently available social network solutions. All of them have been designed as stand alone applications for usage on PC, with client-server principles in mind and data archive stored as a repository of short text messages. It has resulted in the monolithic architecture of the social network client, platform dependency, lack of flexibility in selecting location of the data repository, and over-complicated (often even fully forbidding) schemes of information sharing, reasoning over and joint use of the collected data in cooperation with other services.

For example, nowadays people share a lot of personal information via social networks and the fact that this information belongs to the social network host makes more and more people to consider limiting their activities in social networks, even if they see a value of the service, but at some point the privacy issues start to dominate. Another pity fact is that the huge amount of personal and community information is stored in the system without efficient use, while by applying to it methods of automatic data reasoning would open door for provision of a number of additional services.

In order to further support growth of social network services and allow their equally efficient use from all types of devices, a new solution has to be proposed. The next section provides general description of Smart-M3 smart space reference model. After that we give the basic definition of the new social networks solution, which is followed by a description of one possible implementation of it on top of Smart-M3. At the end of paper we provide a set of key conclusions of this study and a list of references.

II. M3 Smart Space Reference Model

In the book by Diane Cook and Sajal Das the following formal definition of Smart Spaces is given: “Smart Space is able to acquire and apply knowledge about its environment and to adapt to its inhabitants in order to improve their experience in that environment” [6][7]. This definition assumes continues interaction of the user with the surrounding environment that is targeted in continuous adaptation of the services to the current needs of the user. This interaction is enabled by sensing functionality that gathers information about the space and the user; adaptation functionality for reacting to the detected changes; and effecting functionality for changing the surrounding space to benefit the user. Based on the definition the main focus of Smart Spaces is on the user. The general view of the Smart Spaces hierarchy is depicted by Figure 1.

Figure 1. Hierarchical layers of Smart Spaces with user in the center.

Obvious key concepts for any Smart Space are mobility, distribution and context awareness. These are addressed by the recent advances in wireless networking technologies as well as processing and storage capabilities, which have moved mobile and consumer electronics devices beyond their traditional areas of applications and allow their use for a broader scope of services. The significant computing power and high-speed data connections of the modern mobile devices allow them to become information processing and communication hubs that perform rather complex computations locally and distribute the results. This lets multiple devices interact with each other and form ad-hoc dynamic, distributed computation platforms. Together, they form a space where via a number of wireless technologies the users can access a huge variety of services. Similarly, existing and future services form spaces that cater for a variety of needs ranging from browsing to interactive video conversations. These services surround the user all the time and have access to large amounts of data. Over time they can learn the users’ needs and personal preferences, making it possible to build even more advanced services that proactively predict those needs and propose valuable services in the given environment before the users realize it themselves. These layers, each of which can utilize a number of technologies form a smart environment (Smart Space). A further important aspect is that Smart Spaces improve the interaction between users and their physical environments, allowing more efficient consumption of available resources such as energy. Examples of the existing smart space solutions can be found in [8][9].

Based on the analysis of existing smart space environments one can notice that the essential features demanded from all these systems is that they should provide permanent robust infrastructure to store and retrieve information of different kinds from the multitude of different types of the environmental actors. For example one can see the personal space as a framework to interact, manipulate and share information represented using own local semantics.

For the later discussed class of the smart space solutions the following assumptions have been made.

- The key concepts for smart space are mobility, distribution and context awareness.
- The user interacts with a space using multiple agents, where each agent implements certain atom of functionality and services and applications are built as a combined functionality of one or more agents.
- The core of space is information storage A, on top of which reasoning and deductive closure methods create corpus R(A).
- The space information storage and agents are distributed and located on a multitude of devices.
- The user can simultaneously interact with many discrete spaces.

Based on the above defined principles the high-level definition of the target smart space reference model can be illustrated by Figure 2.

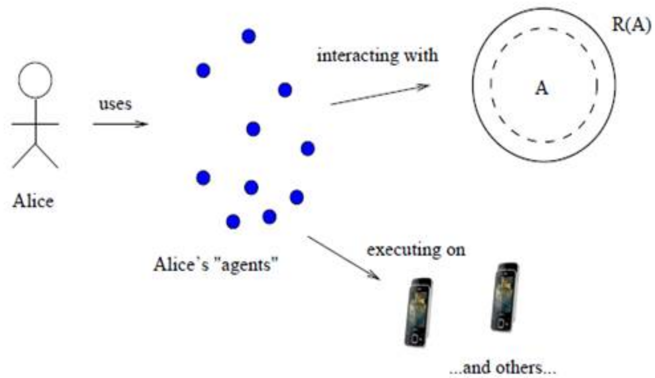

Figure 2. The reference model of Smart-M3 smart space.

On top of this reference model the Smart-M3 solution has been created. Smart-M3 is an interoperability platform that provides mechanisms to share information expressed using RDF. The platform consists of a Semantic Information Broker (SIB) that stores the information, and Knowledge Processors (KP) that acts as agents and can insert, remove, query and subscribe to information. Figure 3 shows a simple functional architecture of Smart-M3.

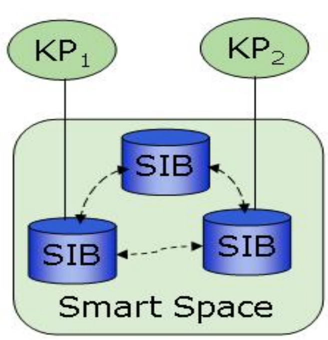

Figure 3. The model of simple functional architecture of Smart-M3.

The information is stored in Smart-M3 according to some standardized or otherwise agreed ontology. But it is important to note that Smart-M3 doesn't require global ontological alignment, instead only local alignment is required. Information sharing helps the participating KPs in gathering relevant context information, which leads to more efficient operation and allows innovative multi-device use cases. During the lifetime SIBs goes through multiple cycles of merge and split operations and the user at the same time could participate in multiples spaces. The physical representation of Smart-M3 reference model is shown by Figure 4.

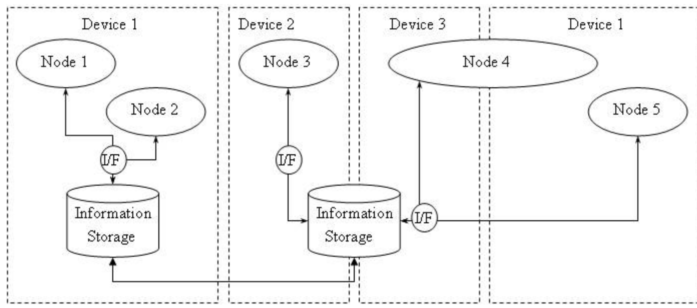

Figure 4. Physical representstion of the reference model of Smart-M3.

Where:

I/F is an *interface* - that provides information exchange between the nodes and information storages. The interface is considered to be fully reliable and does not create additional delay and energy overheads. In this reference model the interface performs a technical function of connecting nodes to information storages. It does not implement logical functions and does not affect information transfer costs. For this reason the interface is not considered in the mathematical model.

Information storages - are also logical units that can be located at several devices and several information storages can be located on one device.

Nodes - are logical elements capable to perform certain actions. One node can be located at several physical devices and several nodes can be located at one device.

Information is described by *information units* (IU) - represented as logical expressions: "subject"-"predicate"-"object" = [true | false], where *subject* is an actor (human or node that performs certain actions), *predicate* is an action that is being performed or supposed to be performed (e.g., "playing music") and *object* is what the action is performed with (e.g., a song being played). The nodes have predefined *behavior rules* defining their actions in line with the received information units.

Based on that the Smart-M3 smart space can consist of the multiple, individual autonomous spaces, with information distributed over multiple devices, including embedded solutions, OVI, PC, mobile, etc., as is shown in Figure 5

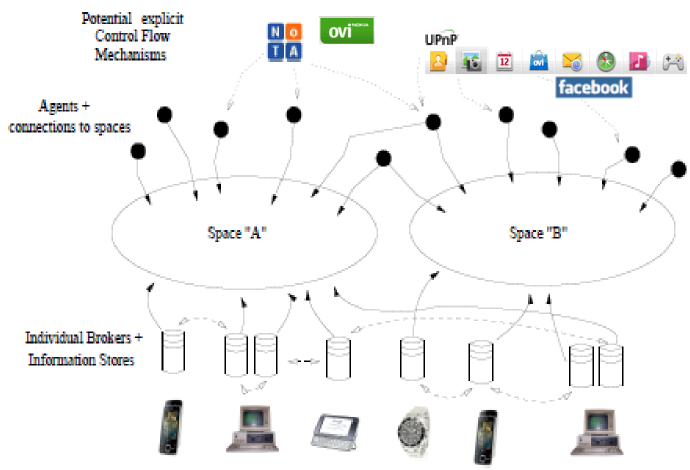

Figure 5. The extended reference model of Smart-M3 smart space.

In a nutshell, the Smart-M3 smart space consists of one or several SIBs. The rules of information usage (user applications) are implemented in KP connected to the smart space via SIBs. The SIBs are responsible for storing smart space information and its sharing. As soon as an information unit becomes available for the SIB, it becomes available for every KP.

As it is mentioned earlier, Knowledge Processors (KPs) are responsible for information processing. In fact the Smart-M3 applications emerge as a combination of one or multiple KPs connected to the corresponding information in the SIBs as illustrated by Figure 6.

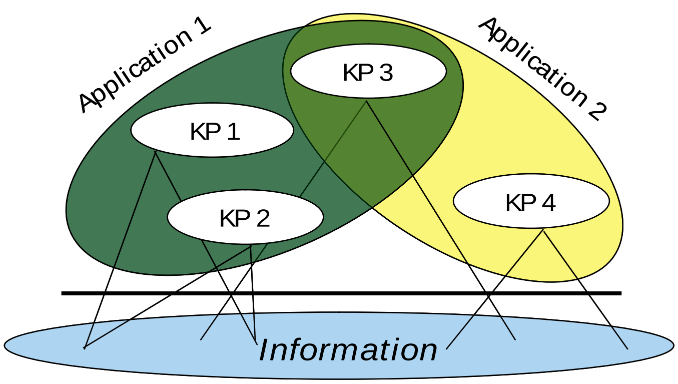

Figure 6. Smart-M3 applications emerge as a combination of KPs connected to SIBs.

It is important to note that the same KP might contribute to the functionality of more than one application. This architecture allows developing new and multiplying existing application with functionality needed for solving current user needs. Also this solution gives developers the great flexibility for deep customization of the application with the minimum overhead, as in most cases the functionality of question can be achieved by changing only one or few KPs, without touching the rest of the application. Altogether the above described features provides the great basis for developing efficient and flexible solutions for different types of user devices, which is exactly what is needed when one think about social network solutions.

III. Description of the Proposed Solution

To start let's see what are the main differentiators and advantages of building social network on top of Smart-M3 comparing to the traditional social network architectures:

1) The internal structure of social network node can be illustrated by the scheme presented in Figure 7.

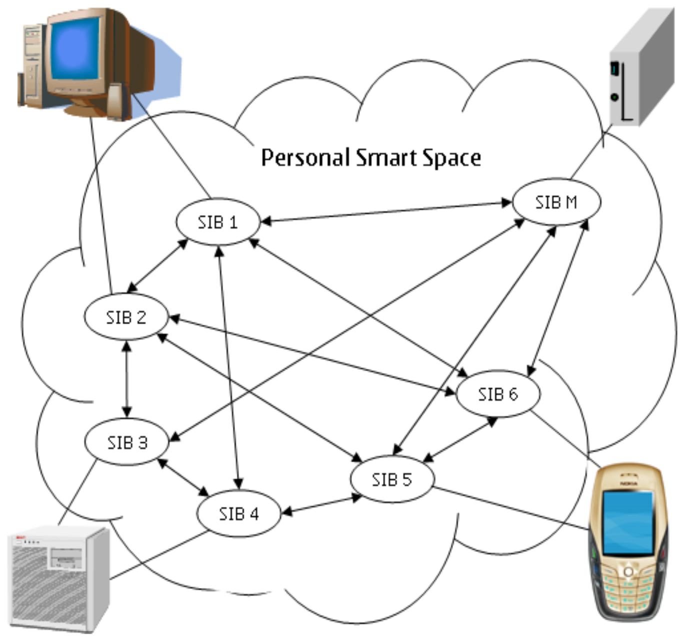

Figure 7. Organization of personal smart space: structure of the social network node.

The proposed social network solution is organized based on peer-to-peer principle (note that here peer-to-peer only refers to the general architectural principle, as oppose to client-server architecture), when all personal data is stored in the space that is under physical control of the owners. So every peer node can be seen as a personal space of the user, which could be physically distributed over a number of devices of different types, e.g., PCs, mobile devices, public and personal data storages, etc. The key feature of each node is that the underlying platform provides a user with the same access capabilities to all elements of the personal data from any device that he/she entered to the personal Smart Space.

2) The social network solution is based on use of Semantic Information Brokers (SIB), which integrates it with other services and information available in the SIB and makes it equally efficient for use from PC and mobile device. Every user has his/her own space, called Personal Smart Space, as is shown in Figure 7. When users decide to become friends in the social network, they not just exchange view/edit access rights to the information pages of each other, but allow real sharing of a certain part of personal space with the new friend peer. This way a group Social Space is created as a merge of certain parts of the personal spaces of group members, where the group members could

be individuals and other already existing user groups, as it is illustrated in Figure 8.

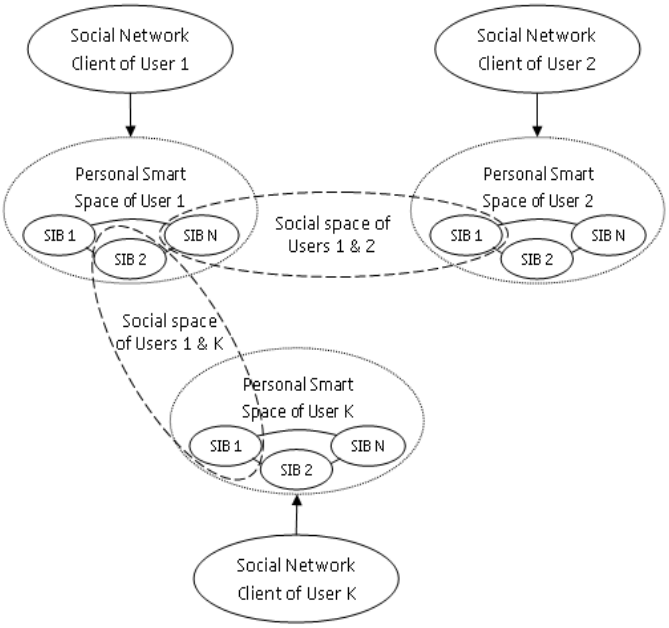

Figure 8. Building social spaces of the friend users as a merge of their personal smart spaces.

Within Smart-M3 definitions the new Social Space is created as a merge of projections of the information sets that the users have decided to share with a given peer (on Figure 4 these spaces are shown by dashed lined ovals). Note that the proposed solution allows user to differentiate friends as much as he/she wants, not restricted by the rules defined by the social network's host. The user can share a lot of personal data with best friends, work related materials with colleagues and the sets of shared information could be completely isolated from each other, or have partial or full overlapping. Also the social space can be expanded to as many users as needed and so the larger group's social space will be created, or alternatively the peers' social spaces can enter into a larger group's space still preserving autonomy.

3) The proposed solution provides great flexibility in defining social network client. The client application is a combination of the M3 applications (hereafter, knowledge processor or KP), which can be seen as a bricks for providing users with the exact functionality that is demanded. Remember that physically any KPs can be located at any device. It is only demanded that they all are connected to the personal social space, i.e., to the user node. Such architecture gives great flexibility for adoption to the actual capabilities of the host device, personalization of the social network client, which includes functional and UI parts. The basic architecture and work principles of the resulting client application can be illustrated by Figure 9.

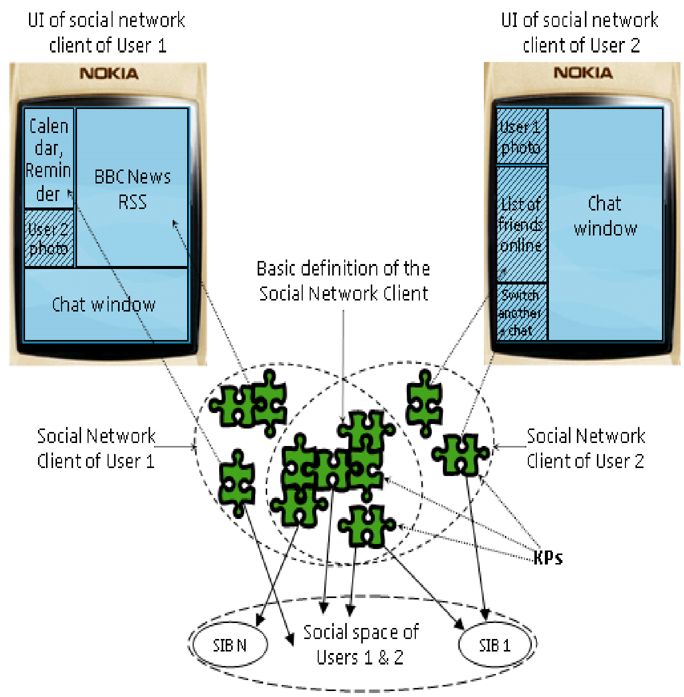

Figure 9. Architecture of the social network client application.

For example, the set of basic configuration definitions of the social network client application can be provided as a part of default distribution package. Then on top of this basic functionality every user can personalize the client by adding KPs that customize functionality and UI. For examples, the additional KPs can be visible on UI, as it is illustrated on Figure 9 by KPs that implement and output "Calendar, Reminder" and "BBC News RSS" functionality for User 1 and "List of friends online" and "switch to another active chat" for User 2. Other KPs can be invisible and used for performing some background actions with the collected data. For example, the user can add KP for performing reasoning over information extracted from SMS and chat engine of the social network, to define what social events in the town might be of a mutual interest for the selected group of friends. Another KP might take care of the smart delivery of important messages to the selected friends, i.e., taking into account all user preferences, especially those that have not been explicitly specified, but obtained from reasoning over user's behavior using all devices and applications in Smart-M3, and so on.

Taking into account the above described advantages of Smart-M3 as a platform for social network we decided to make the first social network application of this type as a framework for establishing professional social networks and supporting all-time cooperation in the distributed R&D projects. This idea comes to our mind, while looking for a solution to facilitate joint work in multi-site projects, we have discovered that none of the existing solutions cover this niche. In fact all the basic modules as in place, e.g., VOIP and shared data repositories, social networks of friends, like LinkedIn and Facebook, but you will not be able to find efficient and easy-to-use framework that bridges all these modules for not only getting all these services via the same application, but most importantly to benefit from data flows and capabilities of all involved modules. Nowadays in most cases such bridging is performed by the user, but the automated intelligent solution is strongly demanded. The required solution should be easily accessible from all user devices, e.g., PCs and mobile devices and the state of project activities including UI and database settings must follow user's migration between the devices. Also a lot of new services such as short voice messages, shared touch-screen whiteboard for participants of teleconference and so on, have to be introduced.

An important feature of target system is that by introducing additional KPs the user should be able to link accounts and services of other social networks into the created framework. So the developed social network client (similarly as it is illustrated in Figure 6 for BBC News RRS) can be an interface and the data processing module for all social networks where the user is registered. As a result the user can use one application and smoothly move his/her social life to the most personalized and appropriate form.

IV. Implementation

As it is described in the previous section, the Social Spaces are defined as a merge of the projections of information sets that the users have decided to share with the given sets of peer nodes. The main consequence of it is that the solution does not require social network-wide definition of the data ontology. Instead every user can stay within the scope of the personal smart space ontology definition and the required commonality will be achieved at the level of joint use of the projections.

The social network client is defined as a Smart-M3 application and consists of a number of knowledge processors that perform designated operations over information in the personal and groups' social spaces and allow access to the service from PCs, and Symbian and MAEMO mobile devices. In this chapter we define only the basic set of KPs and provide high level description of the corresponding operational sequence diagrams required for the service. But as it has been discussed before, one of the key benefits of the proposed solution is that any user will be able to personalize social network client as much as he/she wants and correspondingly the number and variety of the related KPs will grow with the time and even the below described basic set is a subject for continuous updates and modifications.

And before diving into details of the social network solution implementation it is important to say a few words about the underlying development platform. Currently available Smart-M3 open source release contains KP APIs for C/GLib, Python, and Qt/C++. The KPs can be connected to SIB by using either TCP/IP or NoTA H_IN protocol. Eventually more support for different programming languages and connectivity mechanisms are in the to-be-added plan. There is also an ontology library generator for C/GLib API that allows developers to program using ontology concepts instead of using Smart-M3 basic operations and RDF. Ontology library generators for other languages are also forthcoming.

The most recent version of Smart-M3 M3/Sedvice services development platform is available to all developers under open license [10].

The default package of the developed Smart-M3 social network client consists of the following Knowledge Processors:

1) *Manager of Social Spaces*. This KP is responsible for creating new social spaces for user groups and maintaining the list of available social spaces. This is a key functionality as it allows any user create personalized hierarchy of the social spaces around. For example, one can have space for family, elementary school classmates, university classmates, work colleagues and so on. It is clear that these spaces can have certain overlapping, as the same person could be your university classmate and wife. Also when a new peer is identified the user needs to define whether to add it to the existing social space, or create a new space from the scratch or as an extension of another already existing space. On top of this KP allows to search the space by using either peer-to-peer principle or via special "open communities formation" registration servers, which contain only user ID details and basic details how to contact user, but all actual content is on the user side. The example implementation of this KP is presented in the sequence diagram format in Figure 10.

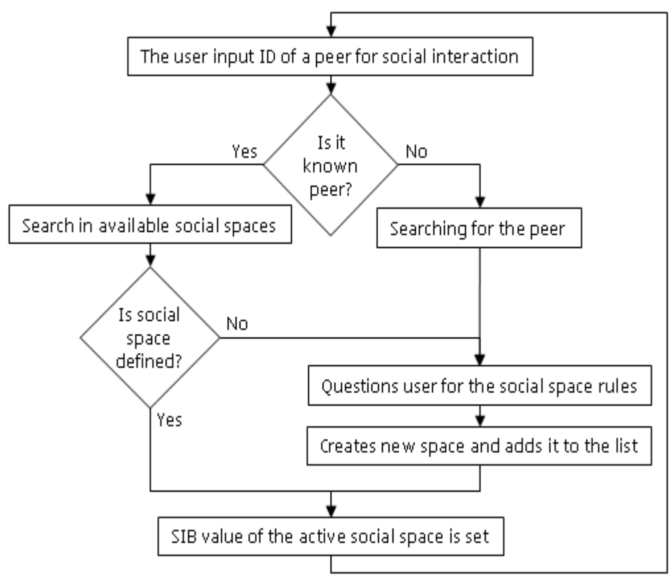

Figure 10. Sequence diagram of the Manager of Social Spaces.

2) *Social Space communicator*. This KP defines all basic queries, subscription methods, handling of collisions and information access rights in a given social space for each person and group. It also provides the user with a set of basic "must to have" services, e.g., the chat client, sharable calendar and organizer, file exchange, image sharing, white board, etc. In fact this client defines the basic common set of services that should be available for all members of the smart space and guaranties that the basic communication mechanisms are in place. One can see it as an internal translator KP that transforms complex functionalities of

various services into a sequence of primitive queries. The sequence diagram for the corresponding KP implementation is presented in Figure 11.

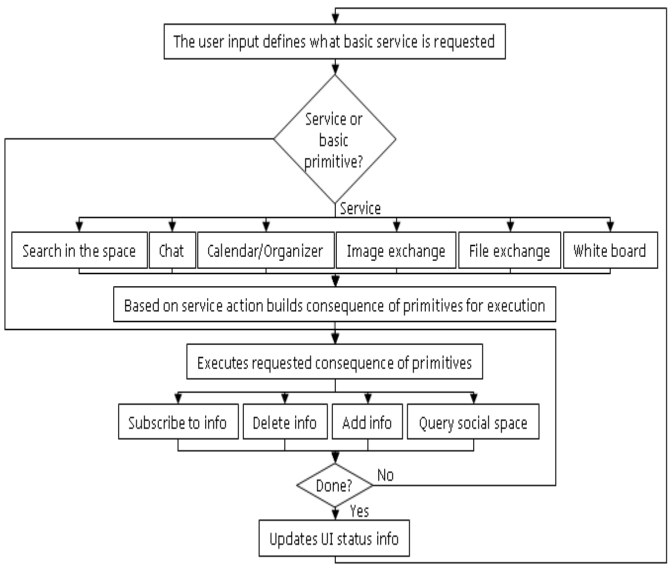

Figure 11. Sequence diagram of the Social Space communicator.

3) *Social Space client UI for PC*. This KP defines the default user interface of the developed social network client for PCs. It handles recognition of the user requests and actions and forwards corresponding commands to the service processing KPs. The sequence diagram of the corresponding implementation of PC UI KP is presented in Figure 12.

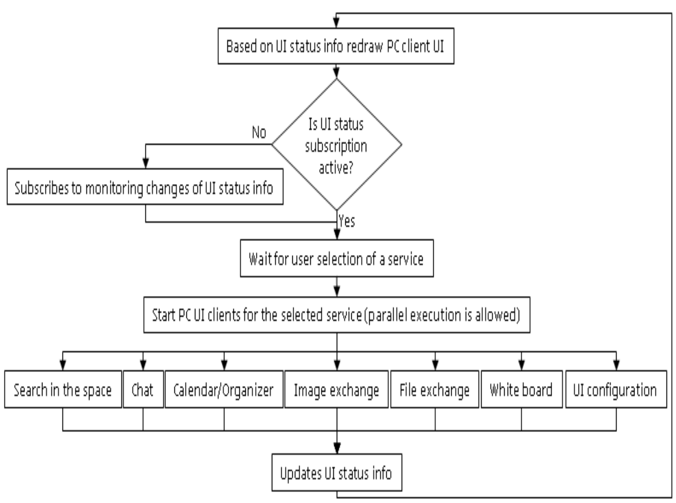

Figure 12. Sequence diagram of the Social Space Client UI for PCs.

Please note that the set of basic services defined in the figure above is just an initial basic set, which later based on users' feedback will be extended by the new services.

4) *Social Space client UI for mobile devices, e.g., for Symbian/MAEMO*. The KP defines the default user interface layout of the developed social network client for Symbian mobile devices. Similar KP for MAEMO platform is currently under development and the solution can be easily extended to any other mobile platforms, which requires implementing only more of the same type of KPs, which will better adopt UI restrictions of the other OS. The sequence diagram of the corresponding KP implementation for Symbian OS is presented in Figure 13.

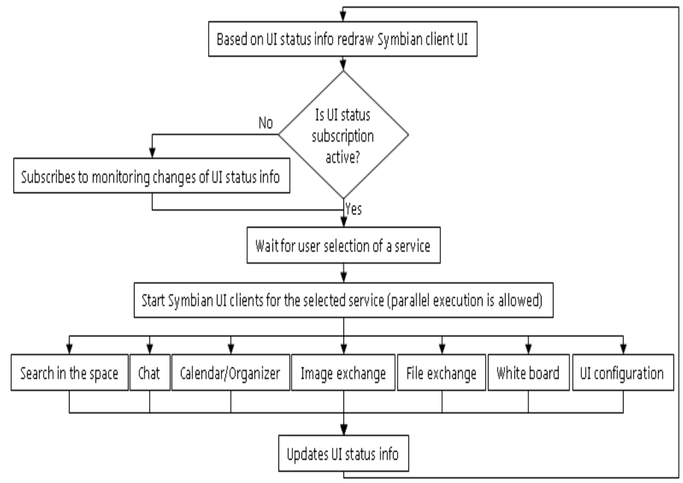

Figure 13. Sequence diagram of the Social Space Client UI for Symbian mobile devices.

5) *Gateway interface to the user accounts in other social networks, e.g., Facebook*. This class of KPs provides interface to user's accounts in other social networks, e.g., Facebook, and saves in SIB structure the information flows, which are coming through our social network client to the extend authorized by the user, the simplest example is by extracting some user-relevant information from analysis of chat messages. Later similar KPs for all popular social networks will be developed and integrated into the default distribution of the package. In Figure 14 you can find the sequence diagram of the corresponding KP gateway implementation for Facebook.

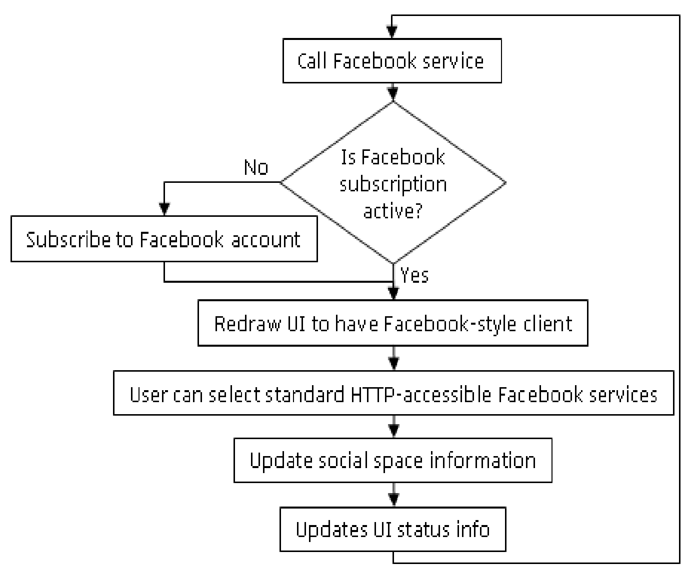

Figure 14. Sequence diagram of Facebook gateway.

6) *Gateway to the large service provision platforms/servers, e.g., OVI*. This class of KPs provide interface for easy and efficient access to the large external service repositories, e.g., Nokia OVI services repository [11]. Through this KP the user gets access to the huge variety of different services and so can use them to form the basic set of pre-provided services in the personal smart space. The similar solutions will be later created to interface other service provision platforms. The sequence diagram of the corresponding OVI gateway KP implementation is presented in Figure 15.

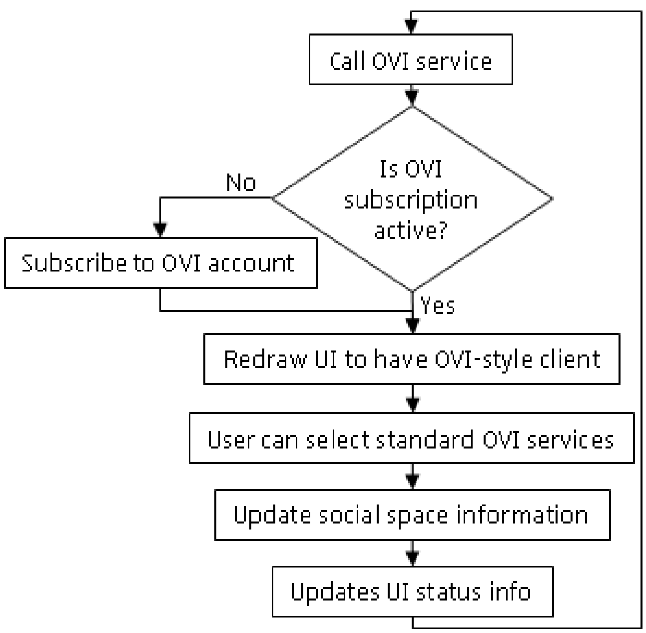

Figure 15. Sequence diagram of the OVI gateway.

The above listed set of KPs forms the very basic group of elements required to define the Smart-M3 social network client functionality. The first implementation of the corresponding application is currently in pilot testing phase. This project is run within scope of the Finnish-Russian University Cooperation in Telecommunication (FRUCT) program [12], which is nowadays one of the largest Open Innovation Academia-to-Industry communities in the Baltic region. The first publicly available solution is expected to be released by the next FRUCT seminar that will take place in the end of April 2010 in Saint-Petersburg, Russia. More information about the project progress can be found from the FRUCT website [12].

V. Discussion and Conclusions

This paper introduces the Smart-M3 platform that allows development of smart space solutions for seamless operation from PCs and mobile devices. The paper gives an overview of main issues that one should take into account in smart spaces design, defines main principles and provides reference model of our Smart-M3 solution, gives general idea about the provided developer's platform and in details discusses one application implemented on top of Smart-M3.

An interesting conclusion that one can derive from this study is about the role of mobile device in the future smart spaces. It is natural for mobile devices to become the personalized access point and interface to the surrounding Smart Spaces due to their availability to the users and their significant processing and storage capabilities. For example, the management functionality should inform the Smart Space about the user preferences and see how to obtain the favorite service of the user from the modules available in the given space. By having access to a large amount of personal information (e.g., calendar, email, etc.) and being carried by the user, the device can learn about the individual preferences and thus find or build up new services and offer them to the user at the most convenient time.

This is especially true when thinking about the social networking application area. This application area is very relevant and important, especially nowadays when more and more joint distributed project are initiated and there is clear understanding that industry and academia must collaborate closely. Creation of a social network for supporting distributed project work, with a feature of automatic data processing and reasoning would be of a great help. The closest nowadays available solution is Ning [13] online platform for creating own social networks. This solution is implemented on top classical web interface, but it is appealing to people who want to create their own social networks around specific interests with design, choice of features and member data. The Ning allows anyone to create own social network for a particular topic or need, catering to specific membership bases. Ning does allow developers to have source level control of their social networks, enabling them to change features and underlying logic. However, despite the significant step towards highly flexible and personalized social network, this solution has a number of critical limitations. It is implemented centralized principle of data storage and web access, which is not suitable for many commercial projects, as it is a key to keep full control over the data and preferably physically have the data only on the devices of member organizations. Secondly, Ning service does not provide good internal tools for data analysis and reasoning, so its integration into smart spaces solution is related to a number of problems. Finally, Ning service is PC platform oriented and porting it to mobile devices will face most of the problems mentioned in Introduction section.

In this paper we propose the new type of social networks solution that makes proactive analysis and reasoning of the going through information flow and derives new knowledge entities and relations for the personal smart spaces of the user. The solution provides a user with flexibility in selecting services and way of UI representation for each access device that the user might want to use. In addition a toolkit for easy development of new personalized modules is provided as a part of standard M3/Sedvice platform. Thanks to the great flexibility we can create equality efficient service clients for PC and mobile devices. Independently of the access device type, the service guaranties access to the same pool of data and preserving successive user experience. Also the proposed architecture maximizes application efficiency, decrease use of all resources, including energy and network traffic, and improves usability of UI. The key here is that the application does not need to contain redundant modules, which are not demanded by a given user. Also thanks to underlying Smart-M3 platform, the solution not only makes reasoning over collected data, but allows easy information exchange with other services. Another important feature for the users is that the solution allows use of the proposed social network together with other popular social networks, which only requires development of the corresponding knowledge processors. We believe that with the time, the social network solutions build on top of smart spaces platform will replace current web-based solutions and become dominant social network solution.

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