

SocioSpace: An Adaptive Service-Oriented Architecture that Integrates Smart Spaces and Social Networks through the IP Multimedia Subsystem

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Smart Spaces offer very promising means to creating context-aware environments. Unfortunately, the lack of enough information about users within Smart Spaces limits their usefulness. We propose a novel solution that integrates smart spaces with social networks through the IP multimedia subsystem to create truly context-aware and adaptive spaces. By utilizing the wealth of user information present within Social Networks, smarter and more adaptive spaces can be created. We therefore propose the design and implementation of SocioSpace, a Smart Spaces framework that utilizes the Social context. We design and implement all components of SocioSpace including the central server, the location management system, social network interfacing components, service delivery server and user agents. We then run various scenarios to test the reliability of the system. The results show the effectiveness of our framework in successfully creating smart spaces that can truly utilize social networks to deliver adaptive services that enhance the users' experiences and make the environment more beneficial to them.

Keywords-smart spaces; social networks; ims; ip multimedia subsystem; service delivery platform; context-aware architecture; next-generation networks

I. INTRODUCTION

There has been a huge interest in social networks with networks like Facebook [1] being the second most visited websites daily in many countries [2][3]. Social networks contain a wealth of information about the users' interests, preferences, education, career, hobbies, etc. that can help build more knowledgeable and smarter spaces. By exploiting the fact that most users carry a mobile device wherever they go and by utilizing the reliable wireless infrastructure and the wealth of information available through social networking, we believe that we can design a truly ubiquitous, intelligent and adaptive environment that significantly enhances the users' experience. [4]

Although a lot of current research projects [8 - 11] worldwide focus on the collection and dissemination of context information in various applications, it is always assumed that context sources can be easily found or are stored in a centralized database dedicated to that context-aware system. In reality, users are very reluctant to enter

their personal preferences into applications that they may not be familiar with. This may simply be due to their busy schedules, their lack of understanding of the benefits of such a context aware environment, or due to privacy concerns. Consequently, many systems are unable to collect enough context information to provide a realistically practical and adaptive environment for the users. Additionally, due to their non-generic designs, most existing context aware solutions cannot support non-specific user profiles and consequently, cannot offer a genuinely autonomous environment. To overcome these constraints, we utilize social network profiles to retrieve relevant user interests and preferences. Most if not all Social Networks provide modules and Application Programming Interfaces (APIs) that allow developers to extract information from a user's profile under their permission [6]. The extracted information can then be used by service delivery components within smart spaces. The different features can be integrated together via the IP Multimedia Subsystem (IMS). There are several features in IMS that make it an excellent candidate for the transport and control layer management.

Our objective is to create a smart adaptive wireless environment. This environment retrieves social information about users within its coverage from Social Networks. It then uses the aggregate of this information to provide services within the domain of the environment that cater to the preferences and interests of these users. The services we shall use to test the system include an adaptive room that changes to meet its occupant's preferences, targeted advertising in the real world, a background music player and other peer-to-peer services. We coin the term SocioSpace to our system because of the utilization of social networks to create smart spaces.

Organization. The remainder of this paper is organized as follows: Section 2 explains the benefits of using IMS for integration of the different SocioSpace components. Section 3 describes the SocioSpace architecture. A detailed discussion of the main components of the architecture are included as well as data transfer amongst the different components. Section 4 describes the performance evaluation methods and scenarios tested. Finally, Section 5 presents some concluding remarks.

II. UTILIZING THE IP MULTIMEDIA SUBSYSTEM

IMS is used to integrate the different components of SocioSpace together and manage sessions and services. In this section we give a quick overview of IMS. We then explain the benefits of using IMS for integration of SocioSpace components.

IMS was developed by the Third Generation partnership Project (3GPP). IMS provides a framework that accommodates current and future services in wired and wireless networks. It encompasses mobile, fixed, packet-switching, and traditional circuit-switching communication systems. IMS integrates services such as video, voice and messaging with personal mobility, presence and terminal mobility. IMS relies heavily on the Session Initiation Protocol (SIP) to manage and control sessions. SIP is an Internet Engineering Task Force (IETF) standard application layer protocol, which is used for initiating and managing an interactive user multimedia session. SIP can setup, modify or terminate data, video conferencing or Internet telephony sessions.

There are several features in IMS that make it an excellent candidate for the transport and control layers of SocioSpace. IMS provides a central database, the Home Subscriber Server (HSS), making it possible for all services to access the information in an easy and standardized way. This allows service providers to offer a coherent set of targeted services to users regardless of their networking interface. IMS also aids in creating an extensible service oriented architecture that is independent of other variables such as mobile device, social network, location, etc. Consequently, service providers are able to develop and release services more regularly by using the conventions, modules and libraries provided by IMS.

IMS Application Servers can be openly programmed to create web services that provide services with access to information stored in the database such as user and space information. IMS Application Servers can also be used to facilitate the connecting to social network APIs and retrieval of relevant social network information.

The integration of social networks with smart spaces and mobile devices through IMS allows the creation of truly smart adaptive environments. These environments consist of ubiquitous applications that utilize the information they have about the entities within the space including user preferences, physical locations, presence, etc. to deliver more relevant and beneficial services. By doing so the users receive new and personalized services such as follow-me services, pervasive mobile games, peer-to-peer capabilities, targeted services, rich multimedia services and more. This context-aware and highly dynamic environment adapts to the changing needs of the user thus increasing the user's overall satisfaction.

III. THE SOCIOSPACE ARCHITECTURE

In this section the proposed framework, system design, architecture and implementation are presented. The system's core features are defined and the main components that make up the system are described in depth. The use of the

underlying IMS network is explained, as well as the interaction between IMS and different system components. The generic user interface specifications are outlined and guidelines for creating SocioSpace client applications are provided.

A. Core System Features

The core system features and services that are present within a SocioSpace system include: smart social spaces, feeds, location based services and user profiles. Each of these features is defined below:

1) Smart Social Spaces

SocioSpace service areas are split into regions called "Spaces". A Space can be defined as an environment that integrates a number of technologies, mobile devices and services into a single adaptive system. These smart spaces recognize individuals and their needs and wants, as well as changes in individuals, changes in needs and wants, and changes in the environment. Within the coverage of a Space, users interface and interact with heterogeneous adaptive services, nearby users and devices within the Space. Spaces consist of large amounts of data that help give the system its context awareness and ability to adapt and provide smart relevant services.

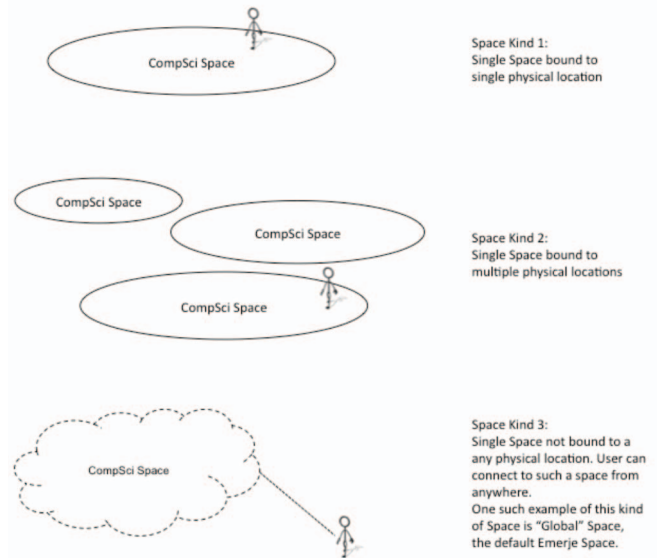


Figure 1: Different kinds of SocioSpace spaces

A SocioSpace Space usually serves a certain physical location and allows users and services within that region to interact with each other. Services are delivered to users and collaboration between different users is made possible. For instance, on campus the Computer Science building can be within the coverage of a single SocioSpace Space. This allows users within the building to collaborate with each other. Different kinds of services can be delivered to the people within the building and hence space. Students can share files, exchange data through peer-to-peer communication and collaborate on schoolwork. Screens can provide services relevant to the people within their vicinity such as news about the department that may be of interest to

them based on whether they are undergraduate students, graduate students, faculty, staff or guests. A multitude of other context aware services can be provided as well.

SocioSpace spaces are not necessarily bound by a single physical location. For instance, if the Computer Science department had multiple buildings across campus they could all be associated with a single Space. Spaces can even be completely independent of physical location. For instance users can choose to connect to the Space they prefer regardless of their current location. By default if a user is not within the coverage of a particular Space they are connected to the “Global” Space. The different possible kinds of spaces are presented in Figure 1.

2) Feeds and Geo-Feeds

Feeds are text-based messages that are submitted by users. In SocioSpace have a maximum length of 140 characters to allow users to send and receive them through text messages on their cell phone if they prefer. Users post feeds to express themselves and say what is on their mind. Feed messages can also explain the current events taking place within a space. Feeds therefore play a major role in creating a “picture” of a space. By reading feeds left by other people within a space, a user can deduce valuable information about the current environment, its users, services and events.

Geo-Feeds are similar to Feeds but they are associated with a certain location. Whether a feed is a regular feed or a Geo-Feed is determined by the space in which it was posted. If the space is associated with a certain location then the feed is also associated with that location and is considered a Geo-Feed. If the feed was posted in a location-independent space then that feed is a regular location-independent Feed as well.

3) Location Based Services & Presence

Location-based services are crucial for the success of SocioSpace since they add a wealth of information that enriches the smart spaces and helps give other services additional value. Presence services, knowing who the people within the space are, what their status is and where they are located makes a space more valuable [7].

Location information and presence are personal private information that the user should have full control over. The user should have control over how much of this data can be shared within the space. They should also have full control over who sees their private information and which parts they get to see. In terms of location, the user should be able to show where they are to certain people or groups and hide their location from others. For presence, this means that the user could show as online to some users while offline, away or busy to others. This shall be managed within SocioSpace by the Presences and Policies Server which will be explained later in Section III.B.

4) User Profiles

When a user registers with the SocioSpace a user profile is generated for them and it is stored in the IMS database HSS. Initially the profile has limited information, but then the system connects to user’s social network(s) and retrieves additional social information and the Social Network Manager (explained in Section III.B) creates a social

context. This social context contains information such as user name, date of birth, gender, hobbies, interests, status, education, work, contact information and more. The user profile also contains information about user location, presence, network information, preferences and a wealth of other information that describes the user. Additionally, the profile has information about user’s friends, family and relationships. This profile information is used by different services to create a more intelligent environment with targeted services that cater to user preferences and interests.

B. Architecture

In this section the SocioSpace architecture is presented. We show how IMS can be utilized to create smart social spaces that provide a multitude of rich services and improve user interaction and communication. Figure 2 shows an abstract view of the SocioSpace architecture. The core of the framework is based on IMS. Modules like SS-CSCF, CUA, etc. communicate by exchanging SIP messages. The exact purpose and functionality of each module within the framework is explained below.

1) SS-CSCF

Since the core of a SocioSpace network consists of IMS, Call Session Control Functions (CSCFs) are present and play a major role in managing the system. SocioSpace is equipped with IMS Proxy CSCF (P-CSCF) and Serving CSCF (S-CSCF).

P-CSCF protects the SocioSpace components and servers. Since the system communication is session based between client applications, the SIP server and other servers such as the location and presence server, they all need to interact with the P-CSCF at application start-up. Dynamic port assignments on both sides need to be requested and stored for later use.

P-CSCF is located within the SocioSpace network and acts as a representative to the user, assisting in authorization and authentication and routing messages from the user agent to the SocioSpace server and vice versa. P-CSCF acts as a proxy server within the system. It receives SIP messages from the user agents, analyzes them and forwards them to the rest of the SocioSpace network where necessary. P-CSCF does not modify the SIP and enclosed SocioSpace-specific messages.

P-CSCF can also act as a User Agent on behalf of the actual Client User Agent. In that case P-CSCF can independently initiate and terminate sessions. This is useful within the SocioSpace network when a user has a scheduled certain tasks or has setup certain preferences and policies. When the appropriate conditions are met P-CSCF executes these requests.

The P-CSCF therefore has multiple key roles within SocioSpace. It acts as an entry point to the rest of the network and other servers including the S-CSCF and SS-AS. P-CSCF is a reliable entry point because it possesses a static public IP address. P-CSCF also routes registration messages to the core of the SocioSpace server for authorization and authentication. Furthermore, P-CSCF forwards all messages from the User Agent to the S-CSCF and replies back to the User Agent with a confirmation. P-CSCF also carries out

less critical functionalities such as compression and decompression of SIP messages.

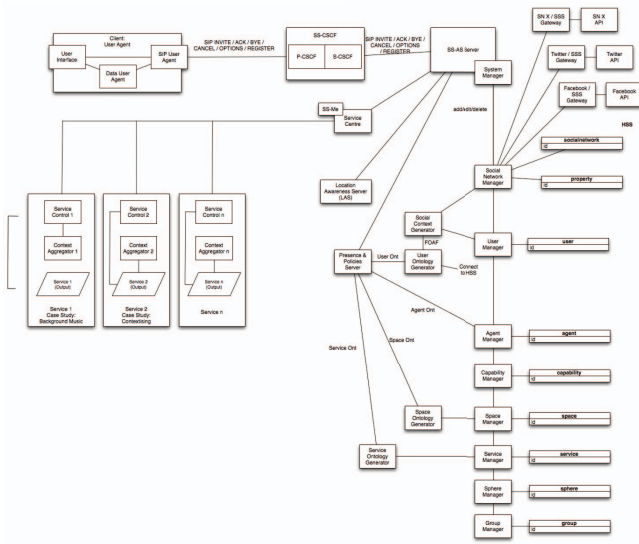


Figure 2: SocioSpace Architecture

S-CSCF server is the core server of the SocioSpace system, it communicates with the user database and handles all registrations, session setups and other SIP messages. Triggers on the S-CSCF advice the server to forward certain messages to SS-AS on the SIP application server.

S-CSCF is the backbone of the IMS part of SocioSpace. Its main functionalities include initiating, managing and terminating sessions. All aspects of a session are managed for the users involved in that session. It is therefore necessary for S-CSCF to be involved in all user communication streams whether incoming or outgoing.

S-CSCF coordinates between different SocioSpace entities such as the User Agent, SS-AS, Location Awareness AS, etc. S-CSCF handles most of the authentication, authorization and registration. It can also manage all aspects of a session from initiation, monitoring, progression and termination. S-CSCF communicates with both the users and services within the SocioSpace Space. S-CSCF maintains the session state that is needed to preserve session information between different SocioSpace entities.

Similar to the P-CSCF, S-CSCF can also act as a User Agent on behalf of the actual Client User Agent. S-CSCF can independently initiate and terminate sessions. S-CSCF can also act as a proxy server and forward messages to SocioSpace entities. According to SIP entities and triggers.

The S-CSCF therefore has multiple key roles within the Emeje networks. It authenticates and registers users that enter or join a Space. It also manages session creation, progression and termination. Sessions are monitored and SIP signaling flows go through the S-CSCF. Furthermore, S-CSCF inspects messages and acts as a proxy server that forwards the messages to the target SocioSpace Application Server. S-CSCF also communicates with the Presence and Policies Server. It also communicates with the Database Manager and Location Awareness Server to aid in the

provision of context awareness and relevant information to other SocioSpace entities.

Since P-CSCF and S-CSCF communicate with each other via standardized SIP and IMS methods, they are combined within SocioSpace to form SS-CSCF. Nonetheless, they continue to perform all the functionalities discussed.

2) SS-Application Server (SS-AS)

SS-AS is a highly customized SIP Application Server that acts as a host for the server-side of SocioSpace. SS-AS acts as the heart of SocioSpace and is responsible for interacting with most major SocioSpace components and coordinating all SocioSpace activities. SocioSpace interacts with the Database Manager to add, edit or delete Database entries. It also communicates with the Location Awareness Manager to make location-aware decisions. For instance, during registration SS-AS asks the Location Awareness Manager for the most suitable Space to connect a user to. SS-AS also communicates with the Social Network Manager to synchronize between SocioSpace and a user's Social Network(s). Social contexts are retrieved from Social Networks or updated via such communication. SS-AS communicates with other components via SIP messages. Although SS-AS cannot directly communicate with the User Agent it can communicate with SS-CSCF and use triggers to reach the User Agent and vice versa.

3) Presence and Policies Server (PPS)

Managing presence and policies is a major requirement for providing a truly omnipresent smart social network services platform. The Presence and Policies Server is responsible for this task. PPS is capable of providing a multitude of different presence information to all users and services within the SocioSpace Space. PPS detects changes to existing states within the SocioSpace network and propagates the changes to all users subscribed to that information. PPS also reads, understands and interacts with services added to the Space by third-party developers.

PPS gathers all information about a single user or service and creates a complete picture of that user. It does the same for all users and services within the SocioSpace Space and hence creates a complete presence picture of the whole Space. The server controls all the information flowing through the presence framework. It coordinates between presences, presence user agents, service agents and watchers. PPS also acts as a proxy server for subscription requests. In order to communicate with User Agents, PPS forwards the messages through the SocioSpace-AS which in turns forwards it to the User Agent through the SS-CSCF. This maintains the integrity and consistency of signaling within the SocioSpace network. SIP is also the method of communication used by PPS but additional presence and contextual information are appended to the header of the SIP messages.

4) Location Awareness Server (LAS)

Location information is essential for the operation of SocioSpace networks and applications. SocioSpace uses the Location Awareness Server (LAS) to extract information about current user location based on the location of their

device. LAS is responsible for all location-based decisions that take place within SocioSpace. It helps give SocioSpace location awareness that results in smarter and more adaptive services. By equipping SocioSpace with location awareness it also becomes possible to localize the services and provide geographically relevant information.

5) *Home Subscriber Server (HSS)*

The Database will hold the tables that will have data of the users and data in their relation, in various tables; database will also have stored procedures, views to support the web service. The HSS will include the following tables: socialnetwork, property, user, agent, capability, space, service, sphere and group.

6) *Client User Agent (CUA)*

The phone client application is developed for mobile devices and is based on SIP. Devices support many different types of access networks so the applications can use any of the standard wireless technologies 3G, EDGE, WiFi or WiMax to access the IMS core. Devices can range from smart phones, PDAs, tablet PCs to laptops and even desktop computers. We will use the Apple iPhone and iPad for tests performance evaluation tests.

7) *Social Network Manager*

In order to make use of the data provided by social networks it is crucial to be able to somehow identify users and their personal profiles and then import their social content into SocioSpace in some sort of standardized format. By providing a reliable portability module, SocioSpace can utilize this information to provide smarter and more adaptive services. However, not all users join the same social networking websites. There is a variety of different Social Networks and users will join different ones based on their age groups, or simply requirements and preferences. Furthermore, it is not out of the ordinary for a user to have multiple profiles on multiple social networks. A mechanism is therefore necessary to extract data from heterogeneous Social Networks and also link profiles across different networks and aggregate the data obtained. Furthermore, by identifying social ties between different people and objects and putting them into groups, better services can be created to cater to that group.

A well defined Social data portability module should therefore be able to query, import and aggregate data from across multiple Social Networking websites and then convert that data into standardized semantic information that can be further interpreted and converted into meaningful information by other entities within SocioSpace. Nonetheless, to create such modules there are significant challenges. The main problem with information extraction from different heterogeneous social networking sources is the availability of different data formats. Each social network exports its data in a different style and format. It is impossible to simply compare diverse un-matching data formats without having some common vocabulary. There must be some kind of mediator format that allows easier interoperability, integration and computations to be performed.

It is better to use an agreed upon semantic representation format such as XML. XML is a general-purpose specification for creating custom markup languages. In particular the Resource Description Framework (RDF) could be used. RDF is a family of World Wide Web Consortium (W3C) specifications, originally designed as a metadata data model, which has come to be used as a general method of modeling information through a variety of syntax formats. RDF can be combined with other technologies to describe people, objects, and the relationships between them in an abstract manner. Social networking websites can become rich data sources that are interpreted by the semantic RDF module running within SocioSpace. This information now becomes machine readable and can be used to provide an enhanced view and rich set of information about the Smart Space. How the standardized data is then interlinked and aggregated to form a meaningful picture is beyond the scope of this module and is discussed in Section X. This module focuses on retrieving the information from a heterogeneity of social networks, identifying a single user's profile on multiple networks and translating the profile data into a unified language.

The syntactic vocabulary to be used to describe the profile data extracted is FOAF (Friend of a Friend). FOAF is a decentralized semantic web technology, and has been designed to allow for integration of data across a variety of applications, web sites, services, and software systems. FOAF syntax is written in XML syntax, and adopts the conventions of RDF. By using FOAF syntax, modules within SocioSpace will be able to exchange and represent social network data in a unified and machine readable manner since FOAF specifies ontology for representing people, objects and the relationships that they share.

8) *Service Manager & Service Control*

The service Manager and all modules associated with it are used for service delivery.

IV. SCENARIOS & PERFORMANCE EVALUATION

Validation and performance evaluation of our Smart Social Spaces framework will be carried out by full implementation of the system. We will develop the different components required to test the system including the full IMS-based server, the Social Networking interface, clients (including their user agents), the service delivery environment and the actual services. We will propose use cases and then test their performance. These use-cases will create different realistic scenarios. We will then run a set of experiments to test the performance of the system under different scenarios. The framework will also be tested under different loads including varying the number of overlay users, varying the mobility of users, varying churn (both joining and departing), varying traffic demands. Each component of the system will also be tested individually to ensure it produces the correct output given a specific input.

A. *Test Setup*

The complete system architecture including the different components is developed to create a real and accurate representation of the proposed framework and design.

Different platforms and programming languages are used for different parts of the system. The core components are developed using the Java 2 Standard Development Kit (J2SE SDK) on a Ubuntu Linux version 10.10 (but compatible with other operating systems). The clients are developed using objective C and Cocoa on the Apple iOS version 4.2 [5].

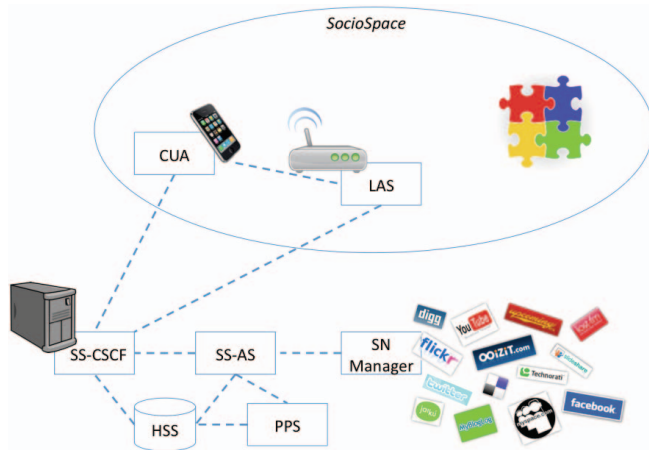


Figure 3: SocioSpace Test Setup

B. Application Scenarios

In this section, different application and service scenarios that benefit from the creation of SocioSpace are presented. These scenarios include contextising (a term we have coined to contextual advertising), adaptive room, background music player, space-tagging and user-to-user communications. A few of these scenarios are presented in Figure 4.

Adaptive Room: In this scenario a room acting as a smart space adapts to the user occupying the room. This could be a hotel room for example where the occupants of the room change over time. As soon as the new occupant enters the room the room environment changes to become more appealing to its new occupant.

Background Music Player: In most retail stores the music playing in the background is based on predicting the music that store's customers would enjoy. With the background music player our objective is to play music that tries to satisfy the largest number of people in the store at any given moment in time. This is achieved by acquiring the social context information of the people in the store and then connecting with music APIs and creating algorithms that try playing music that would be enjoyed by many people currently in the store.

V. CONCLUSION

We designed and implemented "SocioSpace" a Smart Spaces framework that utilizes the Social context. We design and implement of all components of SocioSpace including the central server, the location management system, social network interfacing components, service delivery server and user agents. We then run various scenarios to test the reliability of the system. The results show the effectiveness of our framework in successfully creating smart spaces that can truly utilize social networks to deliver adaptive services

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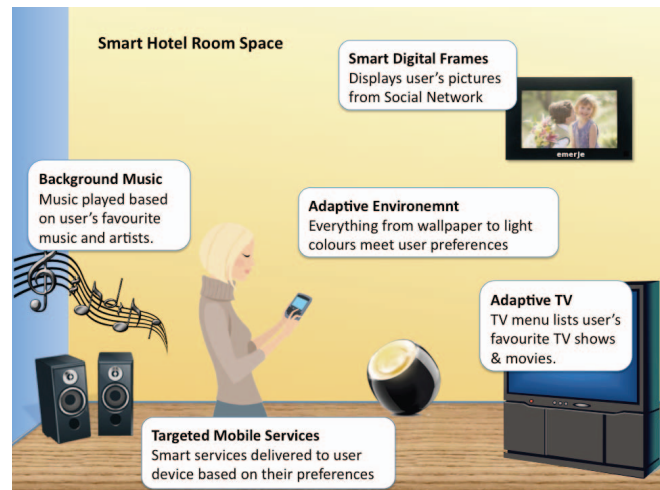


Figure 4: Application Scenarios

REFERENCES

- [1] (2010, Nov.) Facebook. [Online]. <http://facebook.com>
- [2] Facebook. (2011, Feb.) Facebook Statistics. [Online]. <http://www.facebook.com/press/info.php?statistics>
- [3] A. I. Inc. (2011, Feb.) Facebook.com traffic details from Alexa.com. [Online]. http://www.alexa.com/data/details/traffic_details/facebook.com
- [4] K. Seada and C. Perkins, "Social Networks: The Killer App for Wireless Ad Hoc Networks," Nokia Research Centre NRC-TR-2006-010, 2006.
- [5] Joe. (2010, Nov.) Facebook for iPhone. [Online]. <http://www.facebook.com/apps/application.php?id=6628568379>
- [6] S. Counts and K. E. Fisher, "Mobile Social Networking: An Information Grounds Perspective," in *Proceedings of the 41st Annual Hawaii International Conference on System Sciences*, Hawaii, 2008, pp. 153-153.
- [7] B. Chelly and N. Malouch, "Movement and Connectivity Algorithms for Location-Based Mobile Social Networks," in *IEEE International Conference on Wireless and Mobile Computing Networking and Communications, WIMOB '08*, Avignon, France, 2008, pp. 190-195.
- [8] A. T. Campbell, et al., "CenceMe: Injecting Sensing Presence into Social Network Applications using Mobile Phones," in *In Proc. of Ninth ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc '08)*, Hong Kong, 2008.
- [9] N. Pentland and E. a. A., "Social Serendipity: Mobilizing Social Software," *IEEE Pervasive Computing*, vol. 4, no. 2, pp. 28-34, 2009.
- [10] A. Beach, et al., "WhozThat? evolving an ecosystem for context-aware mobile social networks," *IEEE Network*, vol. 22, no. 4, pp. 50-55, Jul. 2008.
- [11] D. Liben-Nowell, J. Novak, R. Kumar, P. Raghavan, and A. Tomkins, "Geographic routing in social networks," *National Academy of Sciences*, vol. 102, no. 33, pp. 11623-11628, 2009.