Ubiquitous Social Network Stack For e-Health Applications

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***Abstract*—Social Networks have contributed the development of e-Health 2.0, which offers promising features of e-Health services any-time and anywhere. In this paper, we address the challenges of adding ubiquity in e-Health 2.0 applications and propose a ubiquity stack that is specialized in capturing temporal and spatial context of a user and can map necessary e-Health services and associated community of interest dynamically. We present our initial proof of concept framework implementation and test results.**

I. Introduction

Social networks have successfully connected millions of people around the globe. Part of this success lies in the fact that social networks use Web2.0 technologies to share multimedia information in formats such as audio, video, text, animation, and image. However, recent advancements in multidisciplinary research domains such as Web 2.0, wireless sensors, smart phones, high speed personal area networking and mobile communication (3G or 3.5G) have contributed to a new era of social networks. For example, various wired or wireless sensors can capture different physical phenomena such as heart beat rate, blood pressure, glucose level, and sweat condition; activities such as walking, sleeping, driving, falling, running, talking, and in a conversation with a friend; environmental parameters such as humidity, temperature, location, altitude etc. With the widespread availability and usage of wearable sensors attached to human body for daily activity and physiological phenomena recognition, ambient context tracking and numerous other purposes have shown promises to add sensory media to the social networks.

Adding sensory media with the social networks opens the door of surrounding every person by ubiquitous networks comprising sensors, and computational devices that are unobtrusively embedded in human body as well as everyday objects such as clothes, and vehicles, and that together create a smart space that are sensitive, adaptive and responsive to the presence of people. In other words, adding sensory media can provide very useful contextual information about a person and/or her surroundings, which can be intelligently shared with the social networks. Moreover, social networks provide ubiquitous means of information consumption, sharing and communication among groups of similar interest or sometimes called community of interest (COI). This vision of social network gives rise to e-Health 2.0 applications where every person will be surrounded by a smart space, which will be able to identify him/her in home or outdoor, recognize his/her actions, emotions, intentions, habitual activities, and health risk and assist the person not only according to his/her individual preferences and needs but also connect with COI based on a given context.

Existing e-Health facilities offer a person to be monitored using several proprietary hardware, software and protocol while she is within the health care provider's boundary or at home. Thus, the existing approaches of e-Health applications fail to fully take advantage of the recent advancements in social networks and cannot be used by general people during their usual daily life activities. We specifically identify three research challenges in order to provide ubiquitous e-Health2.0 services. First, the BSN should be accompanied and easily carried by a human of all ages while he/she is at home or outdoors [1], [2], [3] and be able to detect life threatening or alarming events and send alert messages to health care institutions or concerned COI. In addition, members of health care institutions or COI should be able to communicate with the BSN to access all or a subset of sensors to collect more sensory data. Second, context-aware retrieval of social network services and associated COI is a challenging task because of heterogeneity in social networks such as web sites, emails, social tags and blogs, in their proprietary APIs, in access control and authentication mechanisms and in overwhelming varieties of response methods. Finally, user mobility is part of one's natural movement. Allowing dynamic selection of social network services and COI based on user mobility and context is a challenging task.

In our earlier work [4], [5], we developed a framework called SenseFace that implements the open stack of Internet [6] to dynamically create one's COI depending on the captured sensory data types. The framework also provides a two-way i.e. upstream and downstream communication infrastructure to bridge between BSN and one's social networks. SenseFace uses smart phone as a personal computing device for e-Health applications where a smart phone along with the sensors creates a body sensor network (BSN), store and analyze the raw sensory data, generate a high level primitive data [7], [8] and disseminate the sensory data from the BSN to remote

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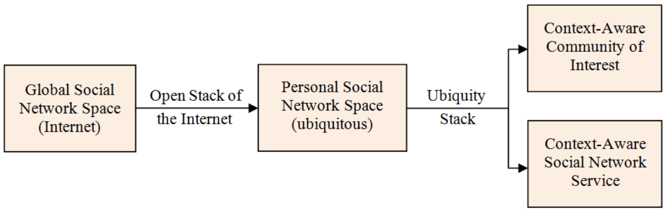

Fig. 1. High level architecture of the proposed ubiquity stack that leverages the open stack of the Internet

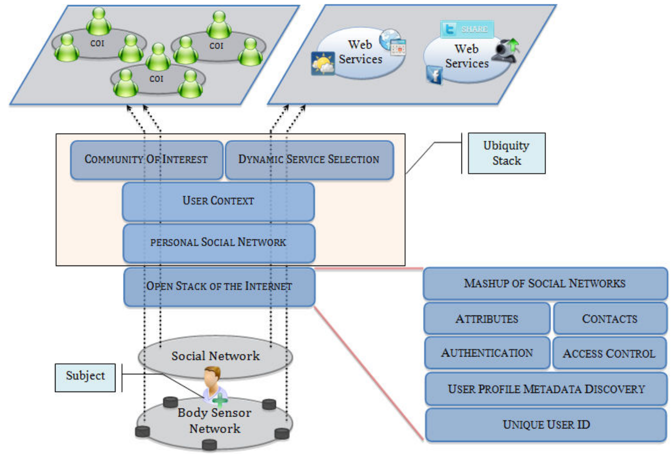

Fig. 2. Proposed ubiquity social network layer, which works as an overlay on top of the open stack of Internet

e-Health service providers or concerned COI and to convey any query from members of COI to the BSN. In this paper, we propose the missing block of social networks i.e. a novel ubiquitous stack that can intelligently follow user mobility and utilize user context coming from both BSN and social networks even if a person is at home or outdoors. We also present our research findings about the optimum candidate technologies and protocols in each layer of the open stack of Internet. The high level framework is shown in Figure 1, details of which is elaborated in Section III.

The rest of the paper is organized as follows. Section II provides a brief description of some related research works. Section III details the ubiquity stack design while section IV shows the implementation details and preliminary test results. Section V concludes the paper.

II. Related Work

Capturing user context using social network and body sensor network data is an attractive area of research and numerous techniques have been studied in the past [9], [10], [11], [12], [13]. For example, context has been studied in areas such as personal context data (user profile, user location, time of system access, to-do list, types of end-device used, and contact list), social context data (social ties through social networks and interactions, types of information shared), and application based context data (types of web services used, bandwidth and reliability requirements of each service, types of protocols and access mechanism needed for each service, URL of each service). Previous researches show that user context can be captured using multimedia information stored in social networks [14], [15], [16], [17], [18], [19], [20], [21]. User context and relations between a group of co-users have been studied [15] in terms of analyzing email, blogs, co-authored papers, and exchanged documents, where the authors present a novel algorithm to cluster users based on content of social network information. The author in [17] presents a framework for building social-networking-enabled context-aware services, called SocialAware.

The research and development efforts in ubiquitous COI management systems in social networks are still quite immature with only a few researches [22]. Some systems assume that the set of COI members is determined a priori and that only registered members can be invoked [23]. Most of these systems statically determine COI formation and mostly work within indoor environment. Frameworks like [24], [25] provide context-aware mechanisms to identify appropriate COI for information sharing. These solutions provide mechanisms to create, discover, and join COI. However, none of them, even though exhibiting potentially interesting features, have yet been applied to support context-awareness in an integrated fashion leaving the burden on service developers to properly handle message forwarding, scheduling, and format adaptation according to collaborating entity characteristics, user profile, and device properties.

III. Ubiquitous Social Network Stack Design

Internet can be thought of as a global social network dataset. Retrieving an individual's attachment with different social network services and social ties depending on user context is a challenging task. Although open stack of Internet provides a conceptual framework, its realization is still premature. However, if properly designed with suitable protocols and technologies, it facilitates discovering, exploring, extracting, and Mashing up one's social network services and social ties from the Internet. One potential limitation of open stack is that it does not have any knowledge about user context. Hence, as the name implies, we propose a mobile or ubiquity stack that works as an overlay on top of the open stack, follows user mobility, and communicates with open stack synchronously or asynchronously. Figure 2 shows the ubiquity stack along with the layers. Now, we elaborate the design of each layers within each stack.

A. Open Stack of Internet

1) Layer1-Unique User ID: Unique user id is the piece of ID e.g. email address, user profile URI, cell phone number, or MAC address of smart phone that is used by the layer above as a key to the user profile.

2) Layer2-User Profile Metadata Discovery: Leveraging 3 sub-layers,this layer takes a resource profile URI as input and provides the location and format of access as output. The top sub-layer, which is Extensible Resource Descriptor (XRD), uses an XML schema to describe a resource e.g. the profile of a user and her relationships to other linked resources or services such as address book, calendar, identity provider, type of authentication supported, and list of involved social networks. The middle sub-layer is called Link-based Resource Descriptor Discovery (LRDD), which is a resource discovery protocol that uses the bottom sub-layer to associate resources using existing link protocols. For example, if fetching social ties from an address book requires three-legged OAuth protocol, the link layer can provide information about how to obtain tokens.

3) Layer3A-Authentication: Authentication layer allows signing in with one's existing social network credentials such as Yahoo, Google, Hotmail, Facebook, Twitter, or any OpenID provider to consume a service. Authentication is realized by a unique OpenID URI provided by an OpenID provider, which points to a user or COI profiles. It allows using a single login information over multiple web services. There are a number of open source initiatives of single sign-in authentication mechanisms that can be integrated with the open stack such as JANRAIN, OpenSSO, and Shibboleth.

4) Layer3B-Access Control: Access control allows a user and member of COI to grant access to their private data, such as address book, from one site e.g. the service provider to another site e.g. consumer site without revealing their identity. Typical access control mechanism for the open stack follows two formats: two-legged and three-legged. Although researchers have proposed new access control mechanisms such as RDFAuth, which is a REST-based authentication mechanism, OAuth still retains its appeal to much of the existing open stack applications.

5) Layer4A-Contacts: This layer works as a transport layer by allowing a web service to organize and publish information such as email, address books and lists of friends about a user's contacts. Typically, existing user information is kept in various proprietary formats (e.g. Google's GData Contacts API, Yahoo's Address Book API, and Microsoft's Live Contacts API). Portable contacts provide a common protocol to share address books of proprietary formats. There are several open source implementation of portable contacts framework that can be integrated with the open stack such as asmx-poco and RPX.

6) Layer4B-Attributes: Using this layer, two sites can exchange attributes such as full name, picture, birthday, country, gender, email, phone number, home address, nickname, height etc. given the authentication session is successful. Among several candidates of this layer OpenID Simple Registration, OpenID 2.0 Attribute Exchange, and OpenSocial People and Friends API are widely accepted.

7) Layer5-Mashup of Social Networks: This layer encapsulates all the APIs, and models to dynamically Mashup social networks that a person uses or relates one with her social ties. For example, a person might be connected to members of COI via email, fax, IM, social tagging, blogs, or existing social networks such as Facebook, Twitter or YouTube, to name a few. In real life, social network is a cloud of services in various formats such as WSDL-based, RESTful, RSS or Atom, proprietary XML/RPC, RDBMS tables, view and stored procedures, spreadsheets, content management systems, text/PDF documents, XML documents, and even unstructured information on internal and external websites. Fortunately, most of the social networks expose information that are Mashable i.e. information having standard interfaces or URIs that can be invoked to consume social network data. Mashables can be anything including Google calendar REST interface, XML/JSON/RSS/RESTful interface of ECG sensor in a BSN containing heart beat, JSON-RPC interface of Yahoo weather API, to name a few. Mashup encapsulates the logic of data processing and manipulation actions including joining, merging, sorting, filtering, constructing, transforming, and clipping social network data. Mashup layer leverages Mashup language called Enterprise Mashup Markup Language (EMML) and Mashup APIs such as Apache Shindig, Yahoo Pipes, Google Maps, Twitter, GoogleAJAXSearch, GoogleAppEngine, YouTube, and Dipity. At the end of Mashup process, it creates entities that can be shared with COI exposed as interfaces such as REST, RSS, Atom, and WSDL to be indexed in databases, consumed on Wiki pages, blogs, websites, portal servers, emails, faxes, or called them directly from a smart phone like iPhone.

Because of the heterogeneity of social networks, realizing the open stack of Internet i.e. exploring the social network space, tracing every domain of one's presence, collecting the types of services or social ties, and indexing this raw information to be accessible for further usage is a challenging task. In our earlier work, we developed ant colony optimization algorithms to tackle such complex task, details of which can be found in [4]. The ant algorithms run as web service, which is configured for each individual. Using ant algorithms, we gather the raw dataset or metadata containing one's social network services and social tie details such as how to consume Facebook services and extract Facebook friends' status, how to connect to a particular web video conferencing service along with participant information, to name a few. This raw dataset is then made available to the ubiquity stack to be consumed from a smart phone or PC as a web service in real-time.

B. Ubiquity Stack Design

The role of this stack (see Figure 2) is to provide a ubiquitous overlay network, which is unique for each person. This stack provides the needed logics, protocols and algorithms to extract one's social network services and COI information from the open stack of Internet, and stores them as personal social network profile. This design provides three benefits. First, it is similar to a user profile that can be stored in a smart phone or a protected web URI, which is available to its owner only. Second, since both the social network service and social tie information is available to this stack either locally or in one's personal web space, the overlay network can operate very fast and independent of the open stack, in case the services provided by open stack is temporarily out of service. Third, a person can specify higher layer concepts such ontologies to define the COI and context. For example, definition of context, which service to use, and who should be the COI in each context is completely vague and varies from person to person. However, this is completely different in the case of ant algorithms operating in the open stack of Internet. For example, connecting to Facebook or Twitter, accessing particular flight information from web, fetching Yahoo calendar events is similar for all the users. A significant difference between the two stacks is that the open stack is stateless while the ubiquity stack maintains a user state lest any user context is not missed. Thus, open stack handles all the global and generic social network information processing while the ubiquity stack facilitates all the personal social network information processing. Next, we briefly describe each layer of this stack.

1) Ubiquity layer1-Personal Social Networks (PSN): This layer plays an important role in the framework by maintain a downstream communication with the open stack. As discussed earlier, the PSN layer provides an updated mirror dataset obtained from the open stack that contains the raw metadata of one's association with all the social network services and social ties. For the optimum case, we assume that the PSN layer only connects to the open stack when there is an update in one's social networks in terms of services or social ties or a request from upper layer to look for any contextual information from the social networks e.g. new message in Twitter or events from Google calendar. That means, the open stack uses a mechanism such as publish-subscribe or AJAX to notify PSN layer. This layer also plays a salient role for the upper layers by facilitating a way of categorizing the raw social ties of a user into high-level categories such as co-author, family, health, study, business, kin, and sports, to name a few. Assume a user context where he/she wants to define the context called 'alarming blood pressure' and map a COI containing a subset from family members, relatives, friends, family physician, nearby colleagues etc. from the available social tie datasets. In this case, the social ties might be decentralized in Facebook, Twitter, phone book, GEDCOMM file etc. To facilitate the higher layer mapping process, a person can employ existing social network analysis algorithms to categorize each social tie. In [4], we provided a Markov process based social network analysis model, which takes one's raw social network dataset as input and categorizes each social tie into one or more of the PSN categories.

2) Ubiquity layer2-User Context: This layer tries to capture a user context from BSN, social networks and past user contexts. In this research, we take into consideration the following types of contexts. First, personal context data, which includes user profile, user location, time of day or week, user activities and physiological information, to-do list, and types of end-device used. Second, social context data including contact list, ties through social networks and interactions. Third, event based context such as appointments and meetings. Fourth, application based context data such as types of services used, bandwidth and reliability requirements of each service, types of protocols and access mechanisms needed for each service, and URI of each service. Fifth, historic context i.e. a user's past context information stored in a database similar to user profile or resource profile. For example, Twitter offers a rich source of user context in terms of current and past activities. Another example is ambient data stored in a smart phone that can provide a rich source of event and context information. Sixth, inter-user context, which defines the types of social network services and COI that differ when one's context changes temporally. For example, a person is engaged in an on-line video conference of project1 meeting from 10 am to 11 am with a group of research groups from three different universities, takes his/her sick child to the family physician's office from 12:30 pm to 1:30 pm, and then joins project2 meeting from 2:30 pm to 4:00 pm with a group of industrial collaborators. In this scenario, the types of people the user interacts with and types of services she uses might be completely different. Seventh, intra-user context describes the difference in the types of services and interactions based on change in one's context throughout a day or week. For example, a person's context changes due to change in location, time of day, types of events he/she faces, and activities.

3) Ubiquity layer3A-Community of Interest: This layer semantically sorts out a sub-set of one's social ties from the PSN category based on a user's context. In our earlier work [4], we showed how Fuzzy Ontology could be used to model social relations in real-life depending on semantics, context, desire and intentions of a person. In this layer, we use Fuzzy Ontology to map a user with a sub-group of PSN members, called the COI so that as soon as the user context changes, the model automatically maps the new COI. The context layer uses one's existing context profile or dynamically finds user context data from BSN or social networks, as described earlier, to locate relevant context such as temporal, event-based, spatial, or ad-hoc. In the case of physiological contexts such as "alarming heart rate", the COI is generated through mapping among sensor profile (ECG sensor), resource profile (smart phone ECG handler application, ECG handler web services), user profiles (family physician, immediate caregiver family member, friend, colleagues, and emergency contacts), context profile (physiological, event-based, spatial, temporal), and services profiles (location services, SMS to daughter, MMS to friend, Fax to family physician).

4) Ubiquity layer3B-Dynamic Service Selection: This layer is co-located with the community of interest layer and tries to answer the type of service a person needs at any given context. This layer is responsible to call the actual social network service to be rendered. Depending on the context of a user or his/her members of COI, a number of social network services might be involved. For example, assume one has access to different audio/video conferencing tools such as SKYPE, ADOBE ConnectPro, TANDBERG Video Conferencing and ooVoo. However, she uses only one of them depending on the context i.e. depending on the type of community involved, types of end device and bandwidth available, and types of mobility pattern etc.

As shown in Figure 1, the framework uses the open stack to filter one's PSN from the global social network space, which can be assumed as the repository of millions of individuals. With the help of the ubiquity stack, the framework can extract

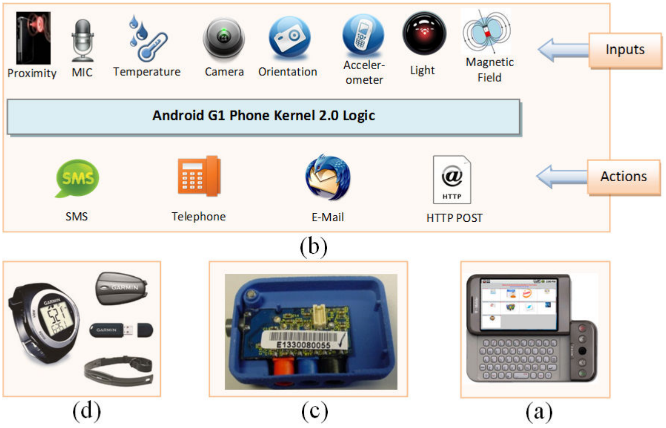

Fig. 3. Sensors and smart phone used to evaluate the framework (a)An HTC dream running Android 2.0, (b) Built-in sensors and communication format comes with the HTC smart phone, (c) SHIMMER ECG kit, and (d) Garmin Forerunner heart beat sensor.

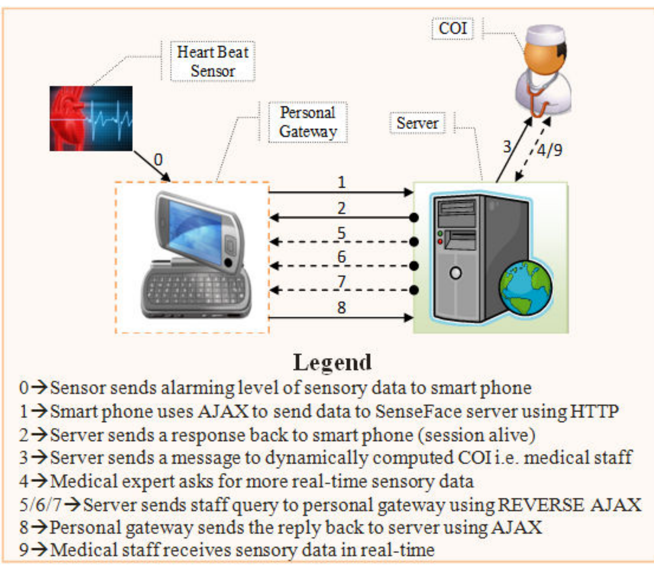

Fig. 4. An implementation scenario of the proposed framework where sensory data contributes to the changes in user context and using the ubiquitous stack, the framework dynamically finds out the members of COI and establish persistent communication between a BSN and members of COI.

the metadata about one's whole set of social network services and social ties. This PSN dataset can be carried by a person ubiquitously through smart phone or stored on-line.

IV. Implementation and Test Results

We have developed a proof of concept framework, which utilizes the open stack and the ubiquity stack. In order to push sensory data, user profile, location information, contact list, to-do list and event calendar from mobile databases, we have developed an application based on Android OS 2.0 smart phone (see Figure 3). We leverage the built-in sensors as well as external wearable ECG sensors to capture different contextual data. In total, 15 participants have participated in evaluating different features of the proposed system over 9 months period from September 2008 to May 2009. The

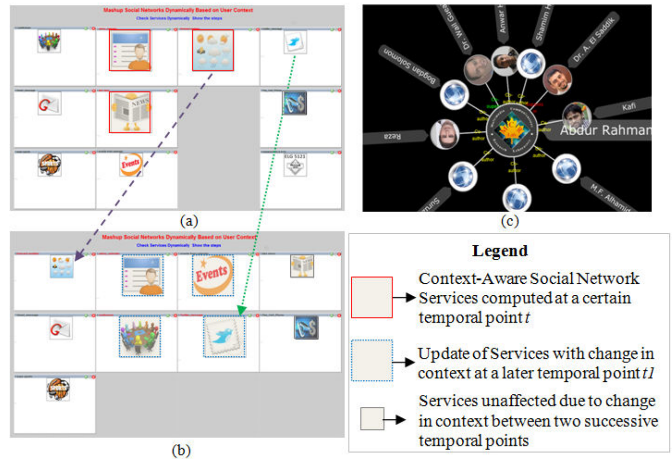

Fig. 5. A web portal showing social network services (a) services with large rectangular icon are services that need immediate attention from the user at a given context, (b) updated user context dynamically updates the portal content as well as layout, and (c) an instance of context-aware retrieval of COI visualized in flash interface.

participants are from different ethnic, age, sex, location, and profession. Tests have been conducted in different times of a day to accommodate varying Internet and cellular network traffic conditions and user context. We have defined some predefined spatial and temporal activities and associated sensory data threshold that should trigger data push to remote server. We have implemented the open stack as a service, detail of which can be found [4]. Figure 4 shows a sample scenario how we capture one's physiological context and vital information through BSN, push them to remote server, and subsequently open a two-way communication channel with different members of COI. Figure 5 shows how we capture user context from social networks and render necessary services and COI. To render the social network services, we have developed a web portal using JavaScript-based open source iMoogle. iMoogle has been configured to dynamically read a JSON file containing the spatial layout and priority of each service to be rendered in a portlet, where the spatial layout and priority are dynamically updated depending on user context. The portal has been implemented for both desktop and mobile clients. The server side programming is done using PHP, Perl, and Python scripts and Java. In addition to the context of a person, the system tries to collect the context of her COI e.g. we find the nearest friend through Facebook using the Yahoo Fire Eagle web services and OAuth protocol. Once the COI has been identified, SenseFace offers a suite of communication facilities as described in [4] such as SMS, MMS, email, Fax, voice mail, blog, GPS and APRS. Next, we evaluate the delay (see Figure 6) in rendering the services by the web portal taking into account the user context as following:

Average round trip delay of an individual service = *(Extracting user context in real-time + The delay posed for creating the JSON containing the skeleton and content of each portal, performing database operation, extracting user context and assigning priorities in the web server + rendering the web*

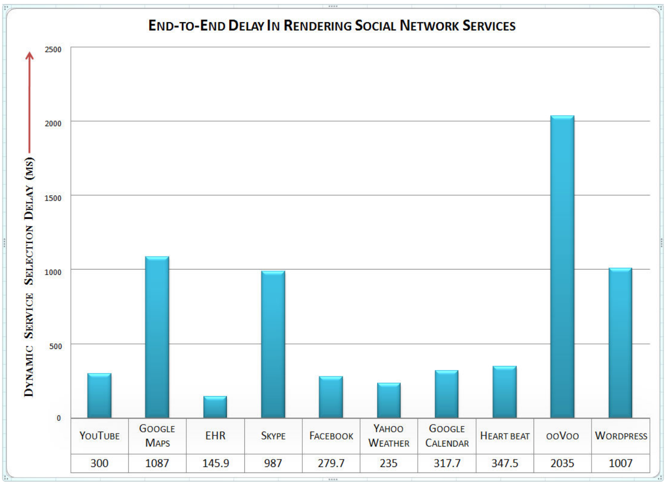

Fig. 6. Average round trip delay in milliseconds in rendering a typical instance of several services leveraging the the proposed stack

services in the portal)/N

where N is the total number of test instances, which is 200. We believe the above test results are acceptable for delay tolerant social networks, which is consistent with the previous researches [17].

V. Conclusion

In this paper, we have presented a framework to add user context with the social networks. We exploit the open stack of Internet and add an overlay on top of it to make social networks personalized. The new social network stack comprises of eight layers, which leverages user profiles, resource profiles and context profiles. We urge that sensory data coming from body sensory network can provide us rich contextual information in addition to user context coming from social networks such as calendar, to-do list, weather networks, Twitter or Facebook messages and historic context profile. Using Web2.0 social network technologies, ant algorithms and fuzzy ontology, we can extract and index the community of interest of a user. We also use the proposed social network stack to dynamically find the services used by a user in distinct contexts. Using off the shelf hardware, social network APIs, and open source tools, we have built a complete context-aware system through sensory data input from a personal body area network and multimedia information from social networks.

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