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A Low-Cost Global Network for Data Collection and Query

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ABSTRACT

We present two complementary research ideas and a prototype framework based on these ideas. The first idea is that by using semantic URIs, Xquery and XML Data Models, HTTP Responses with embedded URIs, it should be possible to construct easily rich web services over SMS for data collection and query. The second idea is that by using several mobile SMS-Web gateways, we can build a low-cost global network with these rich web services. Hospitals in India, including Delek Hospital of Dharamsala, are using the DOTS protocol of the World Health Organisation to fight tuberculosis in Tibetan settlements located in India and Nepal. Our prototype framework implements this protocol.

Categories and Subject Descriptors

C.2.5 [**COMP-COM NETWORKS**]: Local and Wide-Area Networks—*internet*

General Terms

Mobile Web for Development

Keywords

SMS, Data Collection, RestFull

1. INTRODUCTION

The Short Message Service (SMS) available in cellular networks which was originally designed to have a simple way of debugging the system, is a communication channel that has seen a rapid growth lately, with 25 billions SMS being sent in India in 2006. Cellular coverage is very dense now, even in rural and remote area. Despite its simplicity, SMS messaging offers not only typical communication services like peer-to-peer or group comunication, but also access to web services. These SMS-Web services are very beneficial to people in regions where there is no (or expensive) internet connectivity because they offer support for resource sharing, information seeking, and information dissemination. An example of information dissemination, is an SMS tracker service, allowing a user to text an address and a message to an SMS-Web service and have that data published on a web map. We think that the main ingredient to empower SMS with access to richer web services is a RESTFul API to XML Data Models. There is a school of thought that HTTP has frequently been misused by developers to put verbs into their URIs violating the intent of HTTP, which is that each unique URI should refer to a thing, not an action. This is one of the root principles of a web architectural style called REST (REpresentational State Transfer), which was first characterized by Roy Fielding in his doctoral dissertation [4]. The idea behind REST is that web developers should work with HTTP rather than against it, that URIs should name resources, and that response should embedded URIs.

A RESTFul API allows to build efficient mobile SMS-Web gateways and this is the key for building a low-cost global network for data collection and query. This is obviously much simpler than managing databases requests, which suits perfectly to mobile gateways needs in terms of efficiency.

2. ELECTRICITY AND PRICE ISSUES

A central server in a developing country is subject to disrupting operations due to power interruptions. Depending on the frequency and duration of power outages, quite high in Dharamsala for example, the best way to mitigate the effects of recurrent power outages is to install an expensive entreprise-level uninterrupted power supply (UPS) [7]. A cheaper and simpler way to go if we want the server to be safe of power cuts, is to use a server located in a development partner's country together with SMS-WEB gateways on mobile phones. The Android mobile OS has made this feasible at low-cost. For the Tibetan Tuberculosis (TTB) project, we are using an Android based gateway in each Indian state where there is a Tibetan DOTS center. These mobile gateways keep the whole system safe with respect to disrupting operations due to power cuts. Moreover, an Android Server based allows an easy management of SMS processing and sequencing of events, everything being defined in an XML manifest file [1], whereas a GSM card plugged in a computer requires a difficult implementation of handlers, routines and daemons for managing events and requests.

3. SMS, REST WEB SERVICES AND XML CONTENT REPOSITORY

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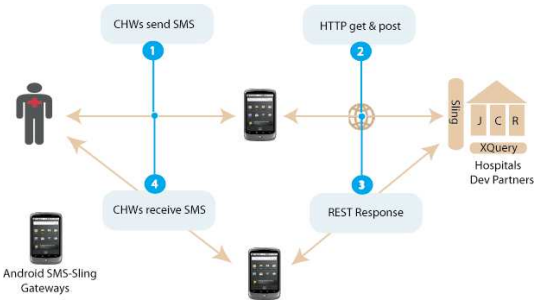

Figure 1: SMS-MobileWeb Information Flow

Our goal is to work towards a better integration of SMS channels into web services by considering SMS has a channel for feeding and retrieving web content. Actually, most of the SMS applications are standalone ones, and SMS hubs are both a piece of the infrastructure and the application development environment. Our work consists in providing a framework around easing the integration of web services and SMS infrastructure (hubs and handsets). This enable more web services to use this channel, and allow more people to access, create and use some web content through SMS.

Our framework is based on Apache-Sling. Apache-Sling is an open source innovative REST based web framework that allows to retrieve data of a Java Content Repository (JCR). On top of that, REST is a very simple, intuitive and discoverable framework that doesn't need any specific formation. This simplicity allows local people to more easily master such a framework and adapt it to other purposes.

It is possible to communicate with the Sling server through HTTP requests in order to perform actions on data. Server-side scripts or servlets are selected by using simple name conventions, i.e. semantic URL. They is no need to build controllers. Data in the JCR can also be retrieved by calling a servlet implementing an XQuery API [3]. Figure 1 shows the architecture of our scalable framework for low-cost global network services.

4. SMS-WEB MOBILE GATEWAYS

4.1 Mobile Android Gateways

Mobile gateways have an intermediate role in the process: they receive SMS requests from phones, package them into an HTTP query and send them to the Remote Repository. Sling will send back an HTTP response to the gateway which will parse the response and send an SMS to the user. This solution has several advantages: Mobile gateways are safe of power cuts and cheap. The price of sending an SMS can be very low if there is a gateway in the state of the user. The communication between the gateway and the Remote Repository being on IP, its cost does not depend on the distance and the server can be located in a development partner country. Several gateways increase the security, the availability and the scalability of the system.

4.2 Web Service for Gateway Localization

Each gateway report its geographic coordinates at regular intervals in the XML database through a REST API as shown in the following XML fragment:

```
<report xmlns="http://tibtec.org/ttb">
  <name>Nexus007</name>
  <mobile>44771234578</mobile>
 <provider>BNL</provider>
  <entries>
       <entry date="2008-06-12T09:56:08.593Z">
         <lat>35.54</lat>
         <lon>76.87</lon>
      </entry>
     <entry date="2008-06-12T09:56:08.593Z">
       <lat>34.10</lat>
       <lon>77.37</lon>
     </entry>
     ....
 </report>
}
```

Figure 2: SMS-MobileWeb Information Flow

The associated web service allows a user to choose the less expensive gateway by requesting through an SMS, a server-side script to determine the optimal gateway with respect to his current location.

4.3 Mobile Gateways and the Tibetan Tuberculosis project

Tibetan settlements are located all over India and Nepal. Hospitals and health centers are shown on the map displayed in figure 2.

The Tibetan community in exile has strikingly high rates of TB and Multi Drug Resistant (MDR) TB cases, which is largely affecting young adults between the ages of 15 - 29. A plan to combat TB has been implemented over a period of 5 years (2008-2013) to reduce both types of the disease. The plan is based on improving TB diagnosis and detection of drug resistance, strengthening the disease case management, increasing the proportion of patients completing treatment, and preventing the disease in high-risk areas. Increased detection of the disease, improved therapy, education and a process of Directly Observed Treatment, Short-course (DOTS) are crucial to rid Tibetans of this scourge.

DOTS is at the heart of the Stop TB Strategy of the World Heath Organization. The DOTS protocol is used all over India and Nepal by all Tibetan hospitals and Health centers raising a difficult problem of decentralized data collection and query.

Our plan is to put mobile gateways in all these hospitals and centers allowing Community Health Workers (CHW) to send low-cost SMS compared to interstate SMS. Moreover, this will make the system scalable. The mobile gateway communicate through GPRS or 3G with servers of development partners in France (INRIA, Grenoble). These servers are not subject to disrupting operations due to power interruptions and have a data backup system.

5. SMS COMPACT SYNTAX

The Android gateway runs on a modified version of RapidAndroid. RapidAndroid is the implementation of RapidSMS, a SMS-based framework for Android that manages data collection and complex workflows, that has proved itself in humanitarian projects for data collection and mass scale monitoring (Malawi, Uganda, ...). RapidAndroid is powerful but some modifications were necessary for it to be usable in our framework. Especially, we have implemented the transfer of data toward the Remote Repository, nothing being saved on the phone, and fitted the API into a RESTfull approach. We have transformed the RapidAndroid Server into an intelligent mobile web gateway for SMS based on a Sling client, having the ability to take decisions depending on SMS content.

The use of a RESTFul API when use in conjunction with a SMS gateway allows to define and use a compact syntax for SMS. This compact syntax reflects the three main tools used in our approach, i.e. semantic URIs, soft links and XQuery over an XML data model. Our current compact syntax for SMS is very simple: keyword [attribute attribute ...]+

We are thinking to improve it to take into account computer experts and not only doctors, nurses and CHW. When an SMS is received, a script in the gateway uses the keyword and originating mobile number to check if the requested operations are valid and to learn about the CHW writing, reading and execution rights. We can distinguish between two processing cases: For data collection, the gateway uses the SMS to construct the URI of the Remote JCR node concerned by the operation. A POST request is then synthesized and transferred by Apache-Sling to a server-side script which store data at the right node in the repository. The Sling HTTP response is coded by the gateway and sent back by SMS to the user. For data query, SMS have the keyword xquery and the list of attributes is transformed by a script on the gateway into an full XQuery request over a JCR node.

For both data collection and data query, soft links (JCR type PATH) are used to build control flows of SMS. This is comparable to the use of links on HTML pages to allow web navigation. Example 5.2 shows how we use soft links in the TTB project.

5.1 TTB Data Collection Example

We give an example of data collection used in TTB project. We want to put in the XML document the result of a sputum analysis. An XML fragment of this document is shown below:

```
<ttb xmlns="http://tibtec.org/ttb">
    <patients>
      ...
      <patient id="13">
         <firstname>Nyima</firstname>
         <surname>Lhamo</surname>
         <email>nyimala@yahoo.fr</firstname>
          <sputums>
             <sputum date="2009-06-7" result="+"/>
             <sputum date="2010-01-3" result="-"/>
          <sputums>
       </patient>
     ...
   </patients>
</ttb>
```

If we want to add the analysis of January 3rd, 2010 for patient 13, we send an SMS with the following content to the Android gateway:

```
put_sputum[13 2009-01-3 negative]
```

Then the gateway will construct the URI:

```
http://wam.inria.fr/ttb/patients/patient[13]/sputums
```

and the new sputum element will be inserted in the xml file via the Apache-Sling POST servlet. The repository will send back a confirmation through the gateway by SMS: New sputum added for patient number 13

5.2 TTB Data Query and Control Flow Example

We give an example of a scenario in TTB project where a data query is used. The use case is that one: a patient needs to learn about CHWs available in Delek hospital, the referent doctor of the CHWs and want to have an appointment. The XML fragment we want to query is below:

```
  <hospital name="delek"
                 xmlns="http://tibtec.org/ttb">
   <chws>
       <chw id="6" doctor="/doctors/doctor[3]">
           <firstname>Lungrick</firstname>
           <surname>Tenzin</surname>
       </chw>
       <chw id="17" doctor="/doctors/doctor[1]">
           <firstname>Phuntsok</firstname>
           <surname>Namgyal</surname>
       </chw>
  </chws>
  ...
 </hospital>
```

For data query, SMS have the keyword xquery: xquery[delek chws]

The Android gateway processes the SMS by transforming attributes of the SMS into an XQuery request appended to the URI of JCR XLM document:

```
http://wam.inria.fr/ttb/content.query.xml?queryType
=xpath\&statement=//hospital[\@name="delek"]/chws
```

This XML response of the web server is parsed and the user receives the names of the two available CHWs in Delek Hospital, together with a template for the next query available:

```
chw[Lungrick Tenzin] chw[Phuntsok Namgyal]
xquery[chw @phone @doctor]
```

If the user choose the second CHW, he can initiate another query in order to know the phone number of Phuntsok Namgyal and the name of the doctor working with this CHW:

```
xquery [chw[2] phone doctor]
```

The gateway build the XQuery, a server-side script execute the query sending back to user the phone mumber of Phuntsok Namgyal and the name of the referent doctor using the soft link /doctors/doctor[1]:

```
phone[9816262389] doctor[Tami Delko]
```

6. CONCLUSIONS

A preliminary experiment of this framework supporting the WHO DOTS protocol for Tuberculosis was done in september 2009 by IT specialists. New experiments will be conducted in September 2010 with mobile gateways in Dharamsala (Delek Hospital) and others places in India and web services running in France (INRIA, Grenoble). These experiments will this time involve doctors, nurses, community health workers and IT specialists.

This framework when used in Dharamsala has to cope with delay, disconnection problems, slow GPRS and a further goal of the project will be to have a fully operational framework by incorporating disconnection tolerance software and by experimenting with late-binding send and receive with respect to all the data channels (SMS, GPRS and WIFI).

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