Extending the Power of Mobile Phone Using Service Oriented Computing*

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Abstract. In 2009, only 3.6% of Kenya's households owned at least one computer; conversely, 63.2% of households owned at least one mobile phone; this is true for many developing countries of Africa. This implies that computing solutions that target mobile phone environments are bound to have greater impact in these countries. However, the inherent constraints of mobile phones present a challenge in implementing viable applications. One solution to this would be to adopt Service Oriented and/or Grid Computing on mobile phones. In this paper, we present results that demonstrate how Service Oriented Computing can enable computation on mobile phones. A java-based questionnaire was implemented as a set of services aimed at overcoming phones' storage limitation. This was achieved via a middleware that was implemented to manage the services; communication among the services running on different phones was via Bluetooth.

Keywords: Service Oriented Computing, Mobile Phone Grid, middleware, Developing Countries of Africa.

1 Introduction

1.1 Background

The developing countries of Africa continue to experience various forms of 'digital divides' [1] one of them being the inability to offer information systems in basic sectors such as health and education. Although still experiencing a mobile phone penetration lag[1] of close to 10 years, Africa has achieved an average penetration level of 41% [2] which is much higher than that of computers. For instance, according to Kenya's 2009 population sensors [3], only 3.6% of households owned at least one computer in comparison with 63.2% of households that owned at least one mobile

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[1] The time gap between mobile phone penetration level in Africa, and the year that same level of penetration was achieved globally.

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phone. With well-designed solutions, the use of these phones can be extended from the traditional use (as mare communication devices) to computing devices on which the much needed e-applications can be executed. However, most phones in use in Africa are low-end and hence presenting a further challenge of using them as computing devices. Due to their versatility, mobile phones offer a fast, cost-effective and accurate way of collecting data at the survey location; they can be used in place of paper questionnaires. Phones also support reliable ways and formats of transferring data for processing and may as well be used for automated pre-processing of the data. There are products and case studies utilizing this ability such the Nokia Data Gathering (NDG) initiative (https://projects.forum.nokia.com/ndg/). NDG is gathering momentum with some success stories reported in projects in agriculture, health, census and child welfare. In Africa, mobile phones have been used to collect data in projects such as [8], [9], [10], and [11].

1.2 Related Work

Service Oriented Computing (SOC) may address many of the issues raised by the use of mobile phones in Africa. This can be achieved by allowing phone users to access certain functionalities that are absent in their phones, as services from other phones. For instance, a user of a *black-and-write* phone may therefore have neither the ability to access a General Packet Radio Service (GPRS) service from which a map can be obtained, nor display a map, but may be able to get that service as directions in text format from a more sophisticated phone. In this case, the latter device can first, get the map from an appropriate source, and then translate this to text directions, assuming the *black-and-white* phone sent it some known relative position(s).

Full and/or partial implementation of the elements of the SOA framework described above can be found in the following service discovery protocols: Universal Description, Discovery and Integration (UDDI) (http://www.uddi.org), Jini (http://www.jini.org/wiki), Service Location Protocol (SLP) (http://www.ietf.org/rfc/rfc2608.txt), Salutation by the Salutation Consortium (http://www.salutation.org), Microsoft's Universal Plug and Play (UPnP) by an industry consortium (http://www.upnp.org) and the Bluetooth Service Discovery Protocol (SDP) (http://www.bluetooth.com). Among these protocols, SLP and UDDI have promising results [6] and [7] for mobile computing environments similar to the one targeted in this paper.

1.3 Contribution and Outline

The Kenya Medical Research Institute (KEMRI) is an organization involved in disease-related research, focusing on malaria. For this, they require constant demographic data, which until recently was collected manually. Mobile phone based applications were developed for KEMRI (www.kemri.org), to address issues of recording clarity/accuracy and delays experienced in the manual data entry. Using mobile phones, data can now be collected faster, recorded more clearly and accurately. Loading of the data into their computer systems is automated and no longer requires data entry personnel. This system is ideal when all the data collected is textual – even the limited storage space of mobile devices will suffice. However, in cases where a researcher wishes to include photos in the collected data, storage space may become a concern.

Building upon a simulation of this scenario to solve the limited storage capacity problem, this paper demonstrates how the use of service-based software applications in mobile phones can be utilized to overcome some of the common problems in mobile devices. The elements of SOC implemented are service description, advertisement, discovery and invocation; service composition is not included in the implementation. Our application converts, by way of example, a part of the Steadman Group's (*www.steadman-group.com*) quantitative survey process into an application that is based on SOC paradigm. The system attempts to replace the paper questionnaires with software forms to be run on mobile phones. The implementation concentrated on closed questionnaires, that is, questionnaires with questions for which there are predefined sets of possible answers. Data collected using the phone is saved locally, or for lack of sufficient storage, in a remote phone. This remote storage is presented and accessed as a service.

The rest of the paper is structured as follows; section 2 describes our SOC system; it describes relevant details on the methodology used for its design. A detailed discussion of its implementation is presented in section 3 while section 4 presents our discussion and further work. A list of references is presented in section 5.

2 The Service Oriented Computing System

The main strength of Service Oriented Computing (SOC) is the concept of 'services'; the design principles behind these services being autonomy, platform-independence, loose coupling, discoverability, reusability, and statelessness. SOC is built over Service Oriented Architecture (SOA), which is defined as "*A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with and use capabilities to produce desired effects consistent with measurable preconditions and expectations*"[4]. As such, SOA links Service Providers, Service Discovery Agency and Service Requester (Client) with each other through publish, find and bind operations[5].

2.1 Service Oriented Architecture (SOA)

From SOA's view, each of services is a complete piece of software (interface and the actual implementation) that implements meaningful business functionality. The key elements of the SOA Framework are:

(a) ***Service Description*** – description of the function(s) and capabilities of the services in unambiguous syntax and semantics
(b) ***Service Advertisement*** – 'announcement' of the presence of a given service description; this is usually done via the service registry or/and directly to service clients

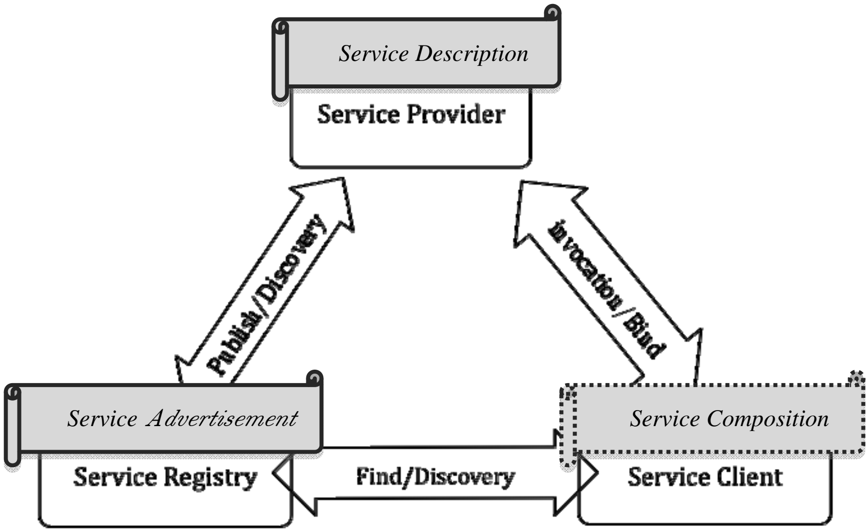


Fig. 1. Basic SOA (Adopted from [5])

(c) ***Service Discovery*** – Formulates the requests for service, matches these requests to specific service description(s) and then initiates communication with the service providers.

(d) ***Service Invocation*** – Transmits requests/results between the service provider and the service user.

(e) ***Service Composition*** – is an optional element responsible for formation of composite services by automatically merging the functionalities of more than one service.

2.2 System Development

2.2.1 System Analysis

This involved carrying out interviews with employees of Steadman Group, to find out the specifics of the organization's research process. The collected responses formed the basis of the case study of the organization. Steadman is a research company that carries out research in the in areas of Market Research, Social Research, Media Monitoring and Management Training. Among other things, Steadman is best known in Kenya for presidential candidate opinion polls. Their research process largely depends on the kind of research project in question, whether qualitative or quantitative. For all projects, the following steps are followed: Field Work → Coding → Scanning → Data Processing →Analysis and Reporting.

2.2.2 System Design

Using the analysis above a mobile phone application based on the Service Oriented Computing paradigm (as described in section 2.1) was proposed. The application was to be installed on all the phones that the researchers carried to the field and worked as per the architecture shown below:

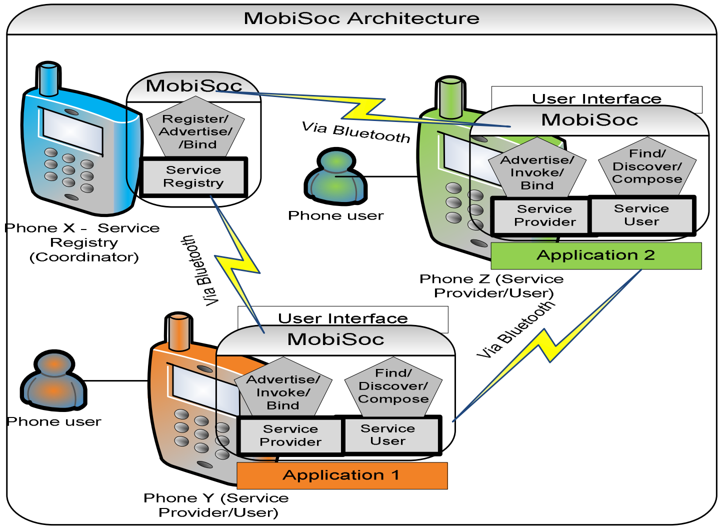


Fig. 2. System Architecture for implementing SOC on mobile phones

As shown in figure 2, main component of the system is MobiSoc; the middleware that handles the SOC functions. MobiSoc is made up of:

(a) ***Service Provider*** – for each installed application, the Service Provider advertises the application, e.g. application 1 (with the Service Registry) as a 'service' that can be invoked. Once a client requests to use the service, it is the work of the Service Provider to invoke and bind the request to the application.

(b) ***Service User*** – this is the interface between the client application (e.g. Application 2 running on Phone Z) and the service application (e.g. Application 1 running on Phone Y). It is responsible for looking up appropriate (through the help of the Service Registry) service(s) on behalf of the client application. In cases where a request for service is satisfied by more than one service, Service User handles 'service composition'.

3 System Implementation

3.1 Overview

Java2ME was used to implement the design described in section 3.4 as follows. A prototype consisting of only one application; a software questionnaire for data collection was implemented. This was implemented in form a java class; ***storageService.java***. In order to support the various SOC routines, three other classes (***sProvider.java***, ***sUser.java*** and ***qnMIDlet.java***) were also implemented. All phones were then treated as peers with each of them being installed with all the four classes.

Research assistants then took out the phones to the field to collect data. The hypothesis was that during the data collection process, some phones would run out of storage space; in this case, such phones would then transparently seek space advertised on other phones in their vicinity. Once all the required data was collected, the phones were then taken back to the office for data extraction and subsequent processing.

When a phone runs out storage, it seeks extra space as a service from a remote device. A layer of middleware (MobiSoc) that utilizes Bluetooth for communication abstracts the communication between the client and the service provider. The middleware comprised of: *Service_Provider*, which advertises and acts as a proxy for the service, and the *Service_User*, which seeks advertisement for services required by a requesting application on the same phone, and also acts as a proxy for the requesting phone (client) in the communication.

Below is a description of each of the 4 classes

(a) ***sProvider.java -*** is responsible for service advertisement and revoking of adverts. It abstracts the underlying communication details, so that a service asking to be advertised need not know of the Bluetooth connection details facilitating this advertisement. A service will create an new instance of the class as follows, to advertise itself

```
sProvider myservice = new sProvider(String UniversallyUniqueID, String ServiceName);
To revoke an advert, the following method is invoked: myservice.sRemove();
```

(b) ***sUser.java*** - is responsible for service discovery and invocation, which it does on behalf of a client who wishes to find and use a given service. It hides the Bluetooth communication details from the client. The use of sUser for discovery and invocation is as follows:

```
sUser wantservice = new sUser(String data_to_be_stored, String UniversallyUniqueID);
```

(c) ***storageService.java*** - is the actual service. It advertises itself by creating a new sProvider(), and stores whatever string data is passed as an argument by a remote instance of sUser() to the new instance of sProvider(). It uses the Record Management System, a set of classes that facilitate usage of a simple database for persistent storage in mobile devices. storageService.java is the service used for demonstration ‘services’ concept of SOC. It is representative of any loosely coupled, remotely accessible service that might be run in a mobile device.

(d) ***qnMIDlet.java*** - is an application used for collecting field data. When it specifies that data should be saved, it may either be saved locally or remotely. When saves are remote, the application sending the record to be saved is a client to the server and it is facilitated by the SOC middleware. The application creates a new instance of sUser(), as described above, to access a service. This class is the application used for demonstration of the working of the SOC middleware. It is representative of any mobile device application that would access a remote service in a remote storage service; the communication between client and another mobile device.

The classes interact as shown in the following sequence diagram:

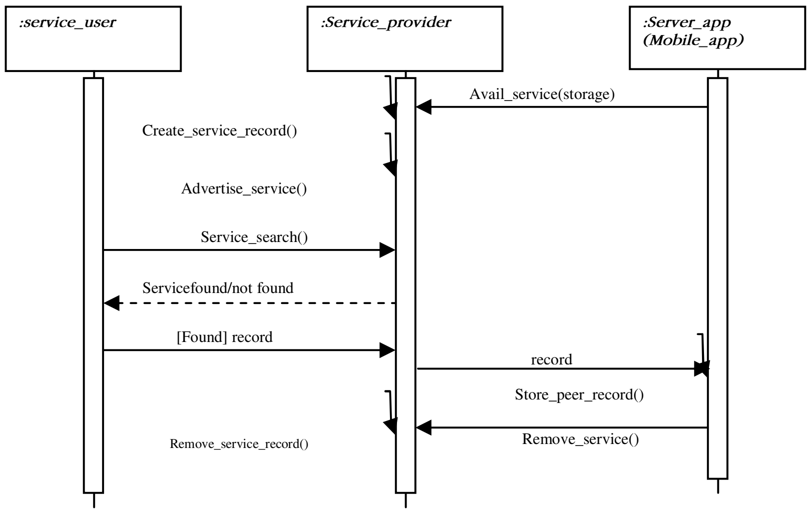


Fig. 3. Service Provider Advertising and Servicing Requests

3.2 Extent to Which SOC Imperatives Are Implemented

The four main aspects of SOA described in section 2.1 were implemented as follows:

(a) ***Service Description***
The storage service profile is comprised of the UUID and the service name. It has no details on host mobility. As for resource availability, as long as a host is advertising the storage service, it means there is at least one space available for remote storage No other details on resource availability are included in the service profile.

(b) ***Advertisement***
The advertisement consists of UUID, and a short service name. When a host device within Bluetooth range of a requesting client advertises storage availability, it is seen by a client no differently from an advert by another host in range, their differences in host address notwithstanding. This advert will also be seen by all requesting clients in range, as will all other advertised services. When a device is out of Bluetooth range, its advertisement will not be seen by clients, meaning a client cannot find an advert for a non-existent or unreachable service.

(c) ***Discovery***
A client discovers an advertised service by using the service's UUID. It need not know the address of the service host, or how the middleware finds the service – it simply makes a request and waits for a response.

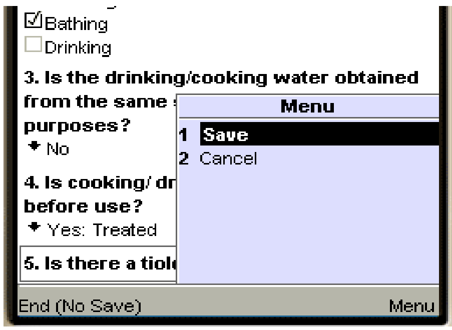
(d) ***Invocation***
When a list of similar services is returned to the requesting client, it selects the first one only. The client does not know what the middleware does to avail this service for its use; neither does the service know the identity of the client

application. No motion profile was implemented to address the issue of unannounced disconnections, neither is there rebinding to a different service if unannounced disconnection occurs.

3.3 System Testing and Evaluation

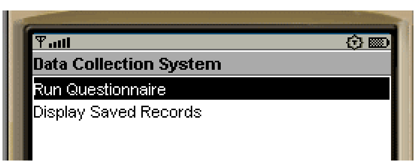
3.3.1 System Start up

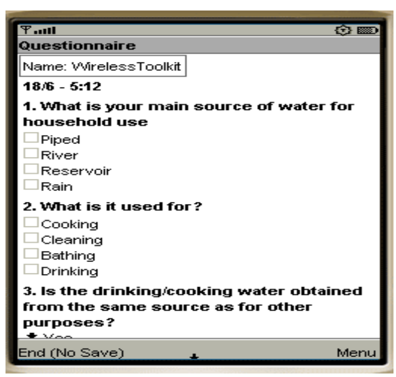
On start-up, the system displays the index screen, which contains two options: to ***Run the Questionnaire*** application, and ***Display Saved Records***.



3.3.2 Run Questionnaire

On selection of the ***Run Questionnaire*** option, the questionnaire application opens. Navigation of this is done using the phone's ***up*** and ***down*** buttons. Selection is done using the phones ***select*** button. The only other commands possible are the ones on the soft-buttons at the bottom right and bottom left of the screen. The Menu has two options – ***Save*** or ***Cancel*** any entries made on this screen so far. The other alternative is to ***End*** the data-entry altogether without saving. The screen capture below show two screens of ***Run Questionnaire*** operation.

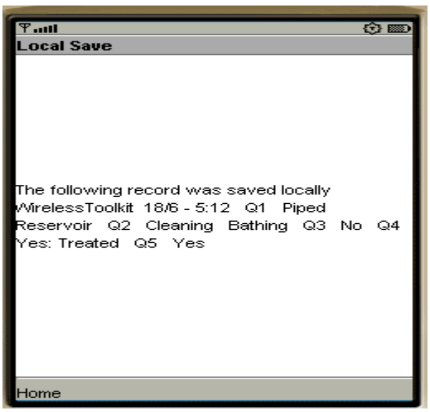


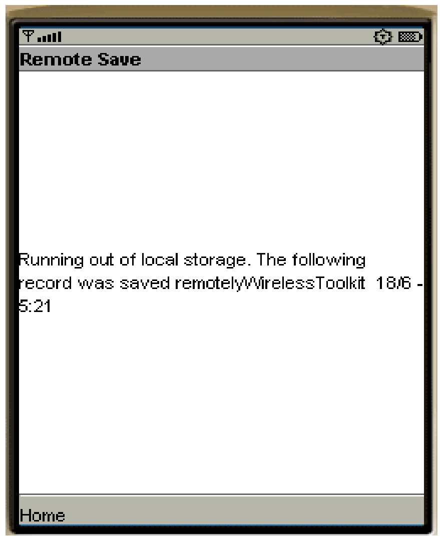


3.3.3 Alerts

Alerts are used to notify the user of ***Local Save*** (when the data is saved locally), ***Remote Save*** (when a device is running low on storage, and gets storage service from a peer device) and ***Local-Save-and-Exit*** (when no device offering service can be found). Alerts are used to notify the user of ***Local Save*** (when the data is saved locally), ***Remote Save*** (when a device is running low on storage, and gets storage service from a peer device) and ***Local-Save-and-Exit*** (when no device offering service can be found).

Below are three examples of alerts





4 Conclusion and Further Work

This paper is a demonstration of the application of service-oriented computing on mobile devices. It provides a roadmap towards realization of *software-for-all* developing countries of Africa. The latter has unique technological challenge/ opportunity where there are more phones than any other form of ICTs. It demonstrates how the concept of designing and implementing systems as a set of services can be used to aid in creating a platform for running applications on mobile phones, their low processing capability not withstanding. SOC was in this case used to help overcome storage limitation. Though storage in mobile phones has today become less of a problem (many phones now have expansion slots for additional memory), this work is aimed at demonstrating that SOC is an option for expanding the computing capability of a mobile phone. The concept of applications being a set of services can be used to provide phones that have low processing power, the capability to seamlessly gain access to computing facilities on another phone. Applications that offer this capability can then be accessible to the client device as services. This way, applications such as health information system and e-learning can be realized in the remotest villages of Africa.

This is an ongoing project and plans are underway to incorporate SOC within a mobile phone grid described in[12]. This will further extend the phone computation power to handle more complex scientific and business applications such as drought prediction. In its current form, the implementation did not take care of security issues and this need to be addressed before the system can be deployed in a real application. In the current application, there is no 'professional' way of select among similar services running different devices. To solve this, an algorithm for selecting the 'best' service provider is being implemented using the bully algorithm approach. Further research towards improving the system efficiency given the resource-constraint and mobility nature of mobile phones would provide an interesting extension to this work. Finally, Steadman, the organisation for which the application was developed, was acquired by another organisation (Synonvate) making system usage evaluation difficult.

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