Leveraging SMS Infrastructure for Internet Access in Developing Countries: Scenarios, Architecture and Research Directions

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Abstract. Short message service (SMS) is now pervasive in many developing countries, thanks to the large footprint of second generation cellular systems, especially GSM. However, in many of these countries, only a handful of privileged end-users have Internet access. This state of affairs is a major impediment to the wide deployment of e-services, since most e-services require Internet access, and so has created a strong motivation for leveraging SMS infrastructure to enable Internet access for e-services in developing countries. This paper introduces real life scenarios, proposes an architecture and discusses the related research issues. The scenarios show that near-real time and even delayed access may be sufficient for many e-services – an option that has been used as the premise upon which the architecture relies. The kiosks are its pillars. They mediate between the widely deployed SMS service and the scarcely available Internet access. Related research issues are identified and discussed. Related work is also summarized.

Keywords: SMS, Internet access, networking for developing countries, e-services.

1 Introduction

Second generation cellular networks, especially Global System for Mobile communications (GSM), have very high growth and penetration rates in most developing countries. In the Republic of Benin (West Africa) for example, the number of GSM Subscriber Identity Module (SIM) cards sold in a year has grown from a couple of thousand in 2000 to close to 4 million in 2008, for a population of around 8 million [1]. The figures are staggering, even if we take into account the fact that a single individual in Benin may own up to five SIM cards at one time (i.e. a SIM card for each of the five different cellular networks in operation in the country) due to the high cost of inter-cellular networks calls.

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This brings the GSM penetration rate to somewhere between 10% and 50%, most probably closer to 50% than 10% since only the well-to-do own several SIM cards. Most other people have either a single SIM card or a maximum of two. On the other hand, the current penetration rate for the Internet is at around 1.8% [2].

Electronic services (E-services) refer to the provisioning of services over the Internet (e.g. e-commerce, e-government). While they can potentially play a key role in most developing countries, the low Internet penetration rate remains a major impediment to their deployment.

On the other hand, short message service (SMS) is ubiquitous in these countries since it now comes as a basic service with GSM offerings. This situation creates the problematic of leveraging SMS infrastructure to enable Internet access for e-services in developing countries – the objective of this paper.

The next section presents real life scenarios. We assume the presence of a functional entity called a kiosk. Although the scenarios are from the specific context of Benin, they clearly illustrate the problematic and similar scenarios are commonly found in most other developing countries. The third section introduces the architecture we propose for the kiosk, and is followed by a discussion of, research directions and related work. We conclude in the last section.

2 Scenarios

Fig. 1 sets the stage. It depicts end-users with cellular phones and SMS access interacting with a kiosk that acts as a mediator between these users and an application server (AS) that is accessible via the Internet and that provides e-services.

The kiosk can either have permanent or intermittent connection to the Internet, or there may even be no connection. In the latter case, a mobile access point can be used to connect the kiosk to the Internet, as discussed in [3]. The access point could be connected to a public bus that moves between the kiosk's location and another kiosk

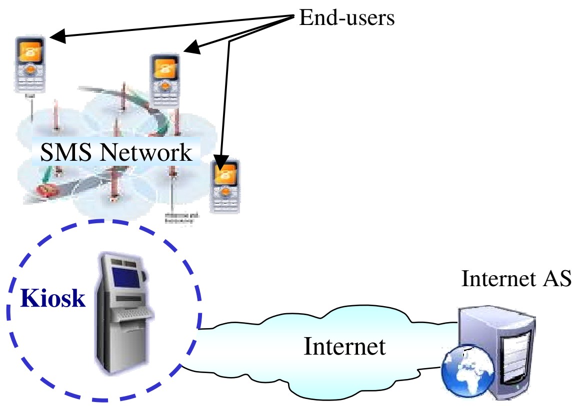

Fig. 1. Accessing Internet services via SMS

(K2) or a neighbouring city with Internet connection. The access point collects the pending requests from the kiosk, delivers them to K2 and gets the responses, and delivers these responses to the first kiosk the next time it gets close enough to it.

An online student registration system, an e-government and an e-banking system are discussed in this section.

2.1 On-line Student Registration

An on-line student registration system was recently launched in Benin to allow students to register for the academic year without having to physically go to the campus. The details of the system are presented below, including how a potential kiosk may make the usage ubiquitous.

To register, the students need to provide a set of information (by filling in a web form), including the student's name, marital status, phone number, email, and birthday, the school name, the major, and the year.

Students with real time Internet access can go on-line and register. However, to meet the needs of students with no real time Internet access, but who do have access to a cellular network that offers basic services such as SMS, an SMS-based registration e-service can be provided as follows (Fig. 2). We assume that the kiosk has a permanent Internet connection. However, cases with intermittent or no connection are also possible.

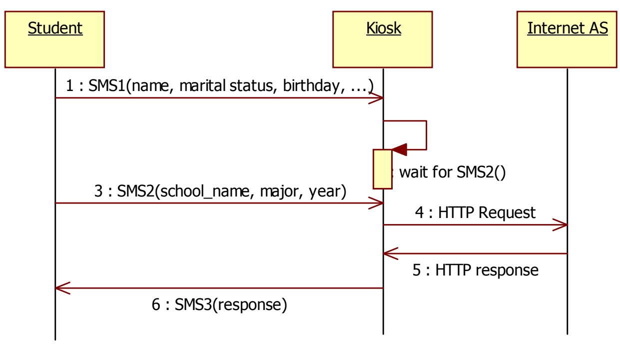

Fig. 2. SMS-based registration e-service

The student sends an SMS message to the kiosk with the required information. Due to the constraints on the SMS message length, the information may be sent in one or more SMS messages. We assume that two messages are required for this service. When the two messages are received, the kiosk creates an Internet/HyperText Transfer Protocol (HTTP) request which it will then send to the Internet AS. When a response is received, the kiosk maps the response into an SMS message that it sends to the students.

2.2 E-Government

There is currently no e-service for passport handling in Benin, although an e-service would significantly increase efficiency. The details of a potential e-service that will increase efficiency are presented below along with a potential kiosk that may aid in making the use pervasive.

Currently, to apply for a passport, applicants must travel to the passport service office in the city of Cotonou. When a request is filed, the applicant receives a receipt that has a unique number. The receipt will be used to track the level of evolution of the demand. Applicants need to continuously monitor the status of their applications, in order to get the passport in a reasonable amount of time (e.g. to avoid delays due to missing documents). The only way to obtain any tracking information is to insert the receipt into one of the reading machines available at the passport office. This procedure may result in applicants having to travel for several kilometres only to determine that their passport is not yet ready.

Sending an SMS to query the application status is much more convenient, easier, and less expensive. Furthermore, the response does not need to be sent in real time.

The e-government service can be supplied via SMS as follows: The applicant sends an SMS message to the kiosk with the receipt number. The kiosk sends an Internet request to a passport AS that will inform the kiosk about the current status of the application (e.g. documents missing, being processed, or passport ready). The kiosk forwards the status to the applicant in an SMS message. The passport AS may be provided by the passport office. It accesses the office's local database in order to consult the status of passport applications.

2.3 E-Banking

Some banks in Benin offer e-banking services. We present below a concrete example of an e-banking service offered by a local bank and show how, as in the previous scenarios, the kiosk may help in making e-banking services ubiquitous.

The e-banking service allows bank clients to execute a set of banking operations online. These include balance checking, viewing the last transaction, and transfers between accounts. Before a client can perform any of these operations, he or she must login using one of the access levels supported by the e-service: 'username/password' that provides basic access for viewing operations, 'digipass' that allows for transfers between accounts, and 'DigipassGO3 for a higher security level.

In this scenario, near real time access or even delayed Internet access may be sufficient for most clients (especially for viewing operations). We assume therefore that the kiosk has intermittent Internet connection. The SMS-based e-banking can work as follows: The client sends an SMS message to the kiosk with the login level and information, and the requested banking operation. The kiosk saves the message locally and replies back with an SMS message confirming the request reception. When an Internet connection becomes available, the kiosk sends the corresponding HTTP request and forwards the response back to the client.

3 Proposed Architecture

Several requirements can be derived from the scenarios above, and they are discussed next. The architectural building blocks that make the kiosk are then presented. We end the section by an illustrative scenario.

3.1 Requirements

The first requirement is that the kiosk should be accessible via both SMS and the Internet. This will enable the end-users/kiosks to send their requests using SMS/Internet, and all the Internet ASs to reply via the Internet.

Second, the kiosk should handle requests in which more than one SMS message is needed to create the corresponding Internet request. This is required for many e-service applications, such as the on-line student registration scenario presented earlier.

Third, the kiosk should support all forms of internet access, including real-time, intermittent and no access. It should also allow the use of the same e-service applications via any of the access forms (e.g. as discussed in the e-banking scenario). This will allow the kiosk to be deployed in different environments, ranging from a big city with real-time Internet access to a small and distant village with no access.

Fourth, in cases where a kiosk has no Internet access, the existing access infrastructures (e.g. GSM, wireless/WiFi) should be used to (temporarily) connect the kiosk to the Internet, and so no new access infrastructure should need to be deployed.

Fifth, in order to be able to handle requests in situations with intermittent or no Internet access, the kiosk should support a store and forward mechanism and therefore provide a storage capability (software and hardware).

Sixth, the kiosk should be scalable in terms of the end-users to be supported; allowing for the handling of more than one end-user at a time and for more than one request initiated by a single end-user.

The last requirement is security. The key features to be addressed are authentication and authorization, confidentiality, and non-repudiation. In the banking scenario, for instance, the end-user should be authenticated and he/she should be able to execute only the operations he/she is allowed to (e.g. an end-user should not transfer money from an account for which he has no authority). Furthermore, the username and password sent for login should be kept strictly confidential

3.2 Architectural Building Blocks

Fig. 3 depicts the architectural building blocks of the kiosk. The kiosk application includes the logic needed for processing incoming SMS requests, and for coordinating the work of the other building blocks. The SMS message handler (SMH) processes received SMS messages (i.e. extract the message content, formats it in a way that the application can understand, and transmits it to the application). It also creates and sends new SMS messages using the SMS access module (SAM). The Internet message handler (IMH) creates and sends new Internet requests and processes received Internet responses. The Internet access module (IAM) handles intermittent and occasional (i.e. only available on some occasions, such as when a mobile access point is in range) connections, and stores and forwards outgoing messages according to the access availability. The SAM can also store and forward SMS messages when there is an intermittent (or occasionally unavailable) SMS connection.

The kiosk supports two types of e-services: customized and non-customized. Each customized e-service is given a unique identifier (ID). The kiosk maintains a mapping between the ID and the associated service address (i.e. the Uniform Resource Identifier -URI). The kiosk also keeps the list of the information required by the e-service to handle a specific request (e.g. a receipt number is required to get the passport application status), and the number of the SMS messages required. The SMS requests need to include the target e-service ID.

For non-customized e-services, no information is kept by the kiosk. The end-user sends the service URI as part of the request SMS.

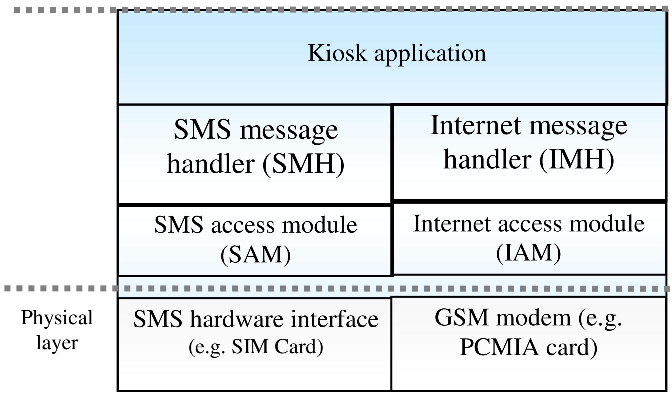

Fig. 3. Overall architecture of the kiosk building blocks

3.2.1 Kiosk Application

When the application receives an SMS request, the request begins in the 'Session Manager' module, that spawns a new 'Session Agent' to handle the request (Fig. 4). In order to support requests from different end-users at the same time, as well as many requests from a single end-user, each session agent is associated to the telephone number from which the SMS request was received and the identifier of the request. The "E-service information database" stores the customized services' information.

To process a request for a customized service, the agent first verifies the number of SMS messages needed and then waits until all of the messages are received or a configurable timeout expires. After all of the messages are received, the agent checks the information received in these messages against that on the database to verify if all of the information needed by the e-service has been provided. If this is not the case, the agent informs the end-user via a response SMS. The agent may give hints about what is missing. The information verification at the kiosk side will optimize the response time, as opposed to the alternative, where the verification is only done on the e-service side (which may take several hours or days).

After a successful verification, the agent calls the appropriate function on the IMH, which creates and sends the corresponding Internet request. When a response is received from the e-service, the agent uses the SMH to map the response to an SMS message and sends it to the end-user.

For non-customized e-services, the received request SMS is directly mapped to an Internet request and sent out.

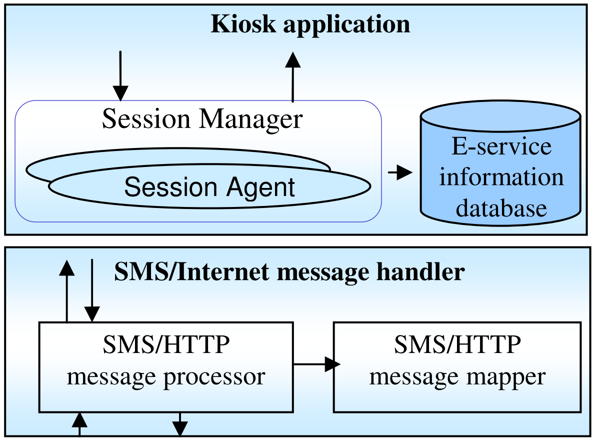

Fig. 4. Architecture of the kiosk application and the SMS/Internet message handler

3.2.2 SMS/Internet Message Handler

The architecture of the SMH and the IMH is shown in Fig. 4. Each handler includes a message processor and a message mapper. When a message arrives for the handler, it is received by the message processor.

When the 'SMS message processor' receives a request, it extracts its content and forwards it to the application. When a response arrives, the processor uses the 'SMS message mapper' to map the response to an SMS message and then sends it to the destination.

Regarding the 'HTTP message processor', when it is asked to send a request, it uses the 'HTTP message mapper' to create the request using the information received from the application, and then it sends the request. The response's content is extracted and forwarded to the application.

3.2.3 Internet Access Module

Fig. 5 depicts the IAM architecture. The messages that need to be sent arrive ate the 'access manager' module. If an Internet access is available, the messages are sent directly to their destination. Otherwise, the manager asks the application (via the message handler) to send a provisional response to the end-user and stores the messages in the 'temporary storage database- TSD'. The TSD also maintains information about the order in which the messages are stored.

The next time Internet access is re-established, this will be detected by the 'Access detector' that will inform the 'message sender'. The latter will then consult the TSD, get the messages waiting for transmission, and sends them out following first-in-first-out algorithm. The arriving messages (i.e. responses) are received by the 'message receiver' and forwarded to the 'Internet Message handler' via the 'access manager'.

The SAM has a similar architecture and it functions in a similar way, except that the request and response processing are reversed. Indeed, the requests are forwarded to the upper layer and the responses are stored if the SMS access is unavailable.

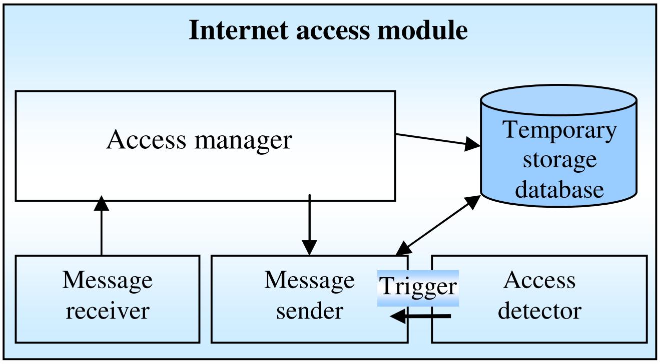

Fig. 5. Architecture of the Internet Access Module

3.3 Illustrative Scenario

Fig. 6 presents the sequence diagram for an end-user requesting the status of their passport application. The end-user sends an SMS request with the passport e-service ID and the receipt number to the kiosk. The request is received by the SAM, which forwards it to the SMH. The SMH processes the message and transmits the formatted message to the kiosk application. The kiosk application checks that the e-service only needs one SMS message, verifies that all the information needed by the e-service has been provided, gets the target URI, and asks the IMH to send a corresponding Internet request. The handler maps the formatted message into an appropriate request and instructs the IAM to send the request. The access module verifies the Internet access availability and sends the request. The response is forwarded back to the end-user following the reverse path of the request.

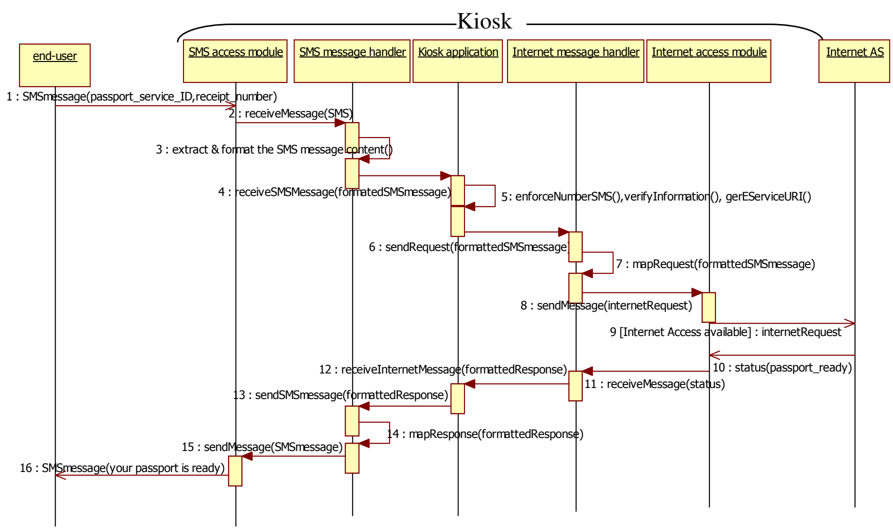

Fig. 6. Scenario sequence diagram

4 Research Directions and Related Work

4.1 Research Directions

The first research direction related to SMS-based e-services is that of a business model. The owner of the kiosk should be identified, and the relationships/interactions (e.g. inter-working for service provisioning, compensation) with the other involved operators (e.g. GSM network provider, Internet AS provider, mobile access point provider) should be specified. For instance, the owner could be a third party or one of the existing operators.

The second direction is session management. In the e-banking scenario, for example, the end-user must login before sending any banking operation request. The login and banking operation require two separate but inter-related Internet requests. The Internet AS accepts the second request only after the first has been executed successfully. The challenge is how to send and execute these two requests when a kiosk may have no Internet access. We cannot afford to wait for the login response before we send the banking request, because the delay between the two may be too long and the session at the AS side may expire before the second request can be received.

Another session-related challenge is how is the session managed at the kiosk side? For instance, how long can a kiosk keep a delayed session (in a case no Internet access) open, before it notifies the client that the request cannot be fulfilled, or to resend the request? Some general patterns may be defined to optimize the session management, depending, for example, on the Internet access behavior (e.g. intermittent, occasional, and periodic).

The third research direction is in routing. In cases with only occasional Internet access, for instance, there may be no route towards the destination when the SMS request is received. The challenge is how to detect a route whenever it becomes available and how to forward the responses back to the source (when a response is created, the route used by the request may no longer be usable). Routing in delay-tolerant networks (DTNs) is one potential approach [4]. DTNs are networks characterized by long delay paths and frequent network partitions [6].

The fourth direction is concrete realization of the kiosk architecture. Existing potential approaches should be analyzed and the more appropriate alternative identified. A centralized approach where all of the kiosk architectural building blocks are deployed in the same box may make kiosk deployment and management easier. The distributed approach with the building blocks in different boxes and well-defined reference points between the blocks may be more scalable, but requires more management effort. Indeed, in addition to managing each box separately, the connections between the boxes should also be managed. Furthermore, the inter-boxes communication may introduce more delays.

The last research direction is security. The end-users should be authenticated, authorization policies applied, and message integrity ensured end-to-end (i.e. between the end-user and the Internet AS) and on the kiosk side. In addition, the messages' confidentiality should also be maintained while the messages travel between nodes. This includes the time when the messages are stored by the kiosk or by intermediary nodes.

4.2 Related Work

We categorize the related work into two classes: related to e-service provisioning via SMS, and related to delayed/asynchronous e-service access. The work discussed in reference [5] falls in the first class, and compares several ways for providing e-services in emerging markets using cell phones, including SMS. The end-users send an SMS to the e-service number with appropriate keywords, and get back the answer via SMS. End-users can also subscribe to an e-service (e.g. weather forecast) and get periodic notifications.

The same paper also discusses the strengths and weaknesses of SMS-based e-services. Strengths include ease of use by end-users, availability on all phones, low network requirements (SMS does not need high bandwidth networks), and low and predictable cost. The weaknesses are mainly related to the illiteracy of emerging countries' populations, the limited input capabilities of mobile phones, and the lack of standardization for SMS-based application development.

However, reference [5] does not discuss the actual architecture to use, nor how the actual services are or can be implemented.

Examples of related work in the second class (i.e. related to delayed e-service access) include the Saami Network Connectivity (SNC) project and the DakNet network. The SNC project [8] aims to provide Internet access to the Saami population of reindeer herders in Swedish Lapland, who relocate many times a year following the natural behavior of reindeer. To allow access to e-services in SNC, each remote area is set as a Network Address Translation (NAT) zone. An application layer gateway is placed at the edge of each zone, in order to terminate the Internet requests and produce outgoing bundles. A bundle encompasses all the information required to complete an Internet action. The data bundles are relayed between gateways using DTN routing [4] through a series of fixed and mobile relay caches.

DakNet was designed to provide Internet access to outlying villages lacking digital communications. It transmits data over short point-to-point links between kiosk's mobile access points. These mobile access points can be mounted on a bus, a motorcycle, or even a bicycle with a small generator. They transport data among the kiosks and the Internet access points.

These two solutions reuse existing access infrastructures (e.g. GSM, WiFi, or satellite radio links) to provide Internet access. However, the kiosks in these solutions are not accessible via both SMS and the Internet, since they only provide Internet access. Furthermore, the requirement for the ability to handle requests where more than one SMS message is needed to create the corresponding Internet request is not relevant for these two systems.

5 Conclusions

This paper proposes an architecture for SMS-based e-services, in which an end-user sends an SMS request to a kiosk with the information the e-service needs, and the kiosk relies the request to the Internet AS. The information needed by the e-service may be sent using more than one SMS message. The kiosk supports different forms of Internet access. When the kiosk receives an SMS request, two alternatives are possible. If Internet access is available, the kiosk maps the SMS request to an Internet request that it sends to the target AS. When the kiosk receives a response, it creates an SMS out of the response content and sends it to the client. If no Internet access is available, the Internet request is stored at the kiosk until the access is recovered. The Internet request may pass through a number of intermediary nodes before it reaches the target AS (e.g. another kiosk, a moving connection point).

The paper also introduces real life scenarios and discusses the related research issues, including business models, session management, routing, kiosk realization and security, security – all of which will continue to be areas of our future research, along with extending the proposed architecture accordingly.

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