Sensing in the Urban Technological Deserts

A Position Paper for Smart Cities in Least Developed Countries

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ABSTRACT

Technological progress in recent years have allowed to produce sensors, on macroscopic and microscopic scales, that are now essential to ubiquitous computing. This paradigm has made the concept of smart cities a reality that is now in synchrony with the needs and requirements for living in this era. Whether it concerns commuters in public transportations or users of existential services such as hospitals, the implementation of smart cities is equally important in developed countries than in the least developed countries. Unfortunately, in the latter, sensors and the associated technologies are not readily available to implement smart cities. It is therefore necessary to identify surrogate ways of sensing the ambiant environment. In this position paper, we discuss the situations in least developed countries and the obstacles to common implementations of smart cities. We also provide a preliminary enumeration of how mobile-phones with SMS-based services and the cultural model can be leveraged to build smart cities in such urban technological deserts.

Keywords

sensing, smart city, sub-Saharan Africa, mobility, ICT4D

1. INTRODUCTION

The concept of *smart cities* has drawn much attention in developed countries, especially regarding the use of ICT to ease the daily life of citizens in their cities. Indeed, *smart cities* are meant to offer, in some ways, ICT-based services in the various domains including transportation, education, commerce, culture and education. In this context, many collaboration initiatives[1] propose to develop and deploy innovative mobile e-services which directly considers the environment of the potential users. In order to provide context-aware information to users, the systems mainly take advantage of sensors which are deployed in urban areas. For example, some cab companies endow their vehicles with GPS modules and provide mobile applications allowing customers to track their arrival when a reservation is made. The same kind of service is also offered by public transport companies. In other cases, sensors (Wi-Fi and accelerometers for instance) integrated to user mobile equipments are used to supply the most suitable routing information from their current location to other places. These data collections, building on the capabilities of the mentioned sensors, are favored by the technological environment: the availability of high-end and personal mobile equipment (smartphones) and the deployment of efficient infrastructures (3G, 4G, Wi-Fi hotspots) for communications in order to access the data.

Obviously, in developing countries and more particularly in sub-Saharan African least developed countries, the urban environment is different. Although the objectives of the concept of *smart cities* are similar, the particularities of the African context change the perspectives in the development of sensor-based mobile e-services. The level of equipment of the population, in terms of high-end mobile devices, is not sufficient and the local structures cannot always afford to make investments so that it is possible to collect information which are useful to the customers (like in the example of companies of taxis). In addition, even when efficient infrastructures of communication are available (3G or 4G networks for instance), their use remains a luxury for a large part of the population. In these regions, it is therefore necessary to change the approach in the way the relevant information for the mobile e-services have to be collected. This approach must take into account two key points:

- the organization of the society: encounters between people are long and frequent (during greetings time for example). This highlights the potential of opportunistic networking.
- the cost of technology: "cheap" technologies (enabling exchanges via SMS or NFC[2] for instance), which, most of the time, generate no additional cost for the users, must be privileged.

[1] A representative example is Smart Urban Spaces (SUS), an European project the goal of which was to define new mobile e-services and also to start building a network of ICT-based *smart cities* - http://www.smarturbanspaces.org/

[2] NFC, which stands for Near Field Communication, is a short range wireless technology (about 10 centimeters) [4]. NFC-enabled devices can read the content of compatible tags (small piece of plastic hardware with electrical circuits) and launch an action corresponding to the collected data.

By considering all the previous elements, the question that we choose to study can be synthesized in the following manner: **what is the proper strategy, in terms of appropriate support to use as sensors, to collect relevant data and publish it in these urban technological deserts, so that useful services can be provided to the townsfolk?**

We focus on the domains of transportation and health care. Indeed, there are interesting topics as the sub-Saharan cities in Africa are becoming more crowded and the way transport systems and pharmacies are operating is not simplifying the life of users. In this context, adapted solutions must be developed to enhance the dissemination of information about traffic and bus hours as well as the availability of particular drugs.

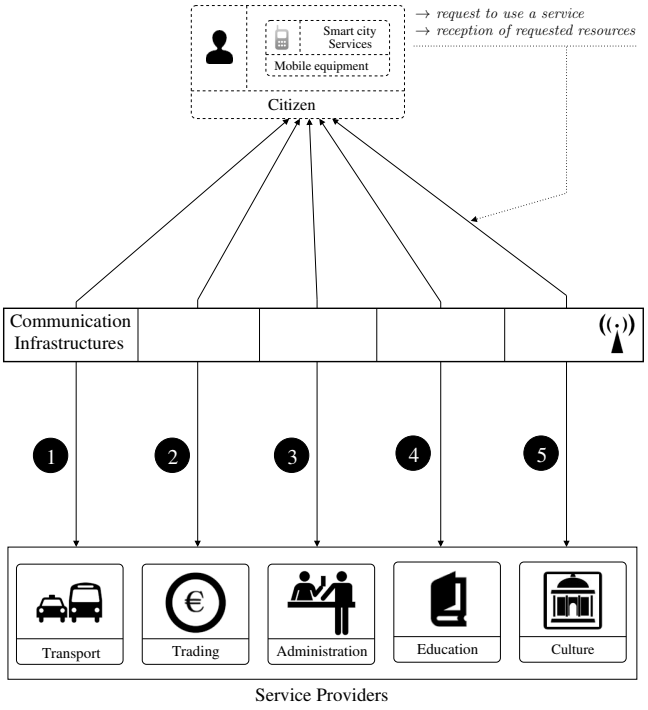
The remainder of the paper is organized as follows. First, we present in more details the concept of *smart cities* and its important role for developing countries like the sub-Saharan regions. Then, we describe the case studies according to the sensing needs in the chosen context. Finally, before concluding, we provide the first outline for an approach to collect the data (in order to propose adapted services to the citizens) from the *smart cities* perspective in a sub-Saharan environment.

2. SMART CITIES

The term *smart cities* refers to the cities which have opted to invest in ICT in order to offer innovative services (in collaboration with service providers) that are able to ease the everyday life of their citizens. It should be noted that the concept of smart cities may also take into account economic, environmental and governance aspects as the goal is to reach a sustainable development [9]. By only considering the technological issues, the terms *digital cities* and *intelligent cities* are also used to characterize *smart cities*. In these cities, the infrastructures of communication are leveraged to improve the functioning of systems which are integrated to the urban environment of the citizens. As mentioned in the introduction, these systems provide services in domains such as transportation, education, commerce, culture or administration. Figure 1 presents examples of interactions between citizens and service providers within the urban area.

In a *smart city*, a citizen could use a mobile device to access the canteen of his workplace or a swimming pool. He could also use the same mobile device to buy transit tickets while viewing the bus hours updated in real time. The services offered by the smart cities are not exclusively oriented towards mobile services, but as the mobility is an essential element of the urban environment, mobile devices and more particularly mobile phones (and their owners) are at the core of the architecture which is usually proposed (Figure 1). In this respect, several projects have been initiated to use the latest technology in mobile telephony to create so-called smart urban spaces built around a set of mobile services[3]. These mobile services aim to simplify the interactions (of every-

[3]A representative example of these projects is the French initiative called Cityizi. The goal was to take advantage of the NFC (Near Field Communication) technology to provide mobile e-ticketing, contactless payment and contextual information services - http://www.cityzi.fr/



1. tickets purchase, validation, etc.
2. electronic payment, loyalty coupons, etc.
3. withdrawals of documents, job offers, etc.
4. schedule, canteen access, etc.
5. virtual visits, interactive works, etc.

Figure 1: Examples of ICT-based interactions within a smart city.

day life) that the citizens perform [2][8]. In practice, mobile services provide the framework from which it is possible to access the resources using so-called mobile devices and their capabilities [11]. The term *mobile*, in this context, refers to devices which can move in the current space according to time (to be in a point A at a given time t_n then move to a point B at a given time t_{n+1}).

Figure 2 describes the environment of deployment regarding mobile services. The resources represent the information to be made available to the users of the services, the technological capabilities are the technologies which equip the mobile terminals (wireless communication technologies), the service providers represent the entities that make the resources accessible by using the capabilities of the considered terminals and the infrastructures are the material elements that establish the communication link (when it is necessary) between the available resources and the mobile devices of the users.

Given the previous elements, and our suggestions outlined for the future of ICT4D in Africa [1], we believe in the relevance of *smart cities* for the regions of sub-Saharan Africa. Indeed, the definition of the concept related to *smart cities* demonstrates its universal scope. The evolution of societies leads to the fact that the organization of public authorities in all parts of the world is intended to provide value added services to their citizens via ICT-based infrastructures. An-

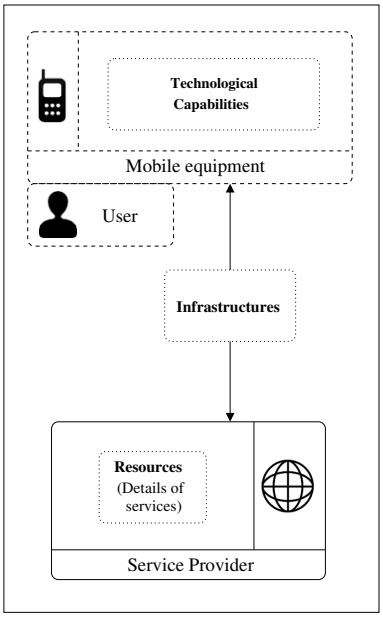


Figure 2: Framework of deployment for mobile services.

other important point lies in the goals of *smart cities* concerning sustainable development. In developing countries, like sub-Saharan Africa, the frontrunner initiatives to move millions of people out of poverty (in a sustainable way) are recurrently said to be based on ICT. In this context, ICT for development (ICT4D) is the latest paradigm which is used to explore the ways to improve the everyday life of people in those countries [5]. This paradigm fits with the perspectives provided by the concept of *smart cities* and thus highlights its essential aspect for developing areas. In addition, it is also essential to avoid wasting the (limited) resources, in terms of vital elements (drugs for instance) and organizational capacity of public services, available to people [6]. In most cases, the use of so-called *intelligent* systems to support the management of these resources can be helpful. Again in this context, the principles laid by the concept of *smart cities* are absolutely necessary in sub-Saharan regions.

3. CASE STUDIES

We discuss in this section two main challenges that are faced by townsfolk in developing countries, and that could be overcome by smart city implementations. The first challenge relates to the ever growing size of cities, which condemns commuters to struggle daily with an unreliable public transportation system. The second challenge is due to the large mismatch between offer and demand in health care services: for example, a patient may have to run through the city, visiting several drug stores, trying to locate by himself a store that has in stock a given drug. We present case studies drawn from the realities of inhabitants of Ouagadougou, the capital city of Burkina Faso, one of the least developed countries in the world.

3.1 City bus operated by "Air maybe"

In the last two decades, the city of Ouagadougou has seen an exponential growth, due to the rural exodus which drove hundreds of thousands of people from the countryside to establish to the city, in the hopes of benefiting from new opportunities. This has lead to the emergence of many suburbs extending in square kilometers around the city. At the same time, the redistribution of economic growth have allowed many citizens to own a second-hand car[4], a motorcycle or a bike. The conjunction of both situations has led to a congestion of traffic inside, and through, the city, and a steady increase of air pollution.

Public transportation has immediately appeared to be the adequate solution to a growing problem. In 2003, a state-owned company, SOTRACO, was founded with the mission to manage public transports in Ouagadougou, steering much hope from public officials and commuters alike. 10 years later, the dissatisfaction is general and at its highest. The company and the city now face several challenges:

(1) Bus schedules are purely fictive. Daily, there are complaints in major journals about commuters waiting from 1 to 3 hours for a bus at stops that supposedly belong to high-frequency lines. Commuters have even coined the name *"Air peut-être"* (a.k.a, "Air maybe") to refer to the national public transport company. There are indeed no fixed timetables, nor can there be, since buses do not run on their own lanes, but must compete with other vehicles in unreliable traffic. Bus stops are also not equipped with display, nor can they be, since unemployment and its corollaries bring along insecurity issues.

(2) The mapping of bus lines poorly fits the needs of users. Indeed, the company can hardly retrieve reliable data for understanding the flow of commuters and updating the network by increase services where needed.

(3) In undeveloped regions, such as Burkina Faso, there is tendency that people entertain socially the economic discrepancies among the rich and the poor. Thus, so far public transportation is getting a lot of bad press as it is associated with the underprivileged. This leads to a vicious circle that executives at SOTRACO claim they wish to break.

3.2 Phantom drugs in ghost pharmacies

In developing countries, cities also differ from rural areas, by the access to health care. Unfortunately, while in villages people always knew which healer to turn to for medications, in cities, drugstores are less reliable. With varying opening schedules and far more varying drug stocks, pharmacies are not properly integrated with the requirements for cities. We note mainly two needs by townsfolk:

(1) At a given time of the day, and at a given location in the city, a patient seeks reliable information on the open pharmacies that can be quickly reached. This information will allow him to avoid waisting his time searching for ghost pharmacies, who have closed unexpectedly that day, have been moved in other locations, or are simply in bankruptcy.

[4]Most of these cars are exported from Europe or the USA, where they no longer meet the environmental standards

(2) Second, because of the small sizes of the pharmacies, the stock of available drugs as well as the variety of drugs are limited. Thus, health care professionals and patients (or their care takers) may require precise information on the kinds of drugs that can be found at a given pharmacy. This is specially the case of high-profile drugs or drugs that are known to be temporarily out of stock in the country.

4. TOWARDS DEMATERIALIZED SENSORS

The case studies presented in previous sections may appear resolvable in a straightforward way, given the technological achievements that the research community has driven in recent years. Unfortunately, in most developing countries, implementing smart cities using the same technologies as in developed countries is virtually infeasible:

- public spirit is constantly threatened, making less desirable the option for placing different types of technology devices at public places. For example, TV displays at bus stops will probably be stolen or broken during the regular strikes.
- data traffic is still costly, at least following the annual revenue per inhabitant, making most 3G-based services a luxury.
- smart city requirements are not yet perceived as concrete problems, in developing countries, compared to food and security problems in Africa. Thus, public authorities may not afford, politically, to take initiatives to drive the implementations of smart cities as in developed countries.
- finally, there is a challenge in developing countries to create consortia where all stakeholders would agree on the directions to take in order to drive growth and improve services. Thus, users must take in their own hands the implementations of smart cities.

4.1 Leveraging the cultural model

To implement smart cities in developing countries and collect useful data for mobile services provisioning, we propose to build on two realities: (1) only low cost technology can be afforded by most people, and companies, because of the limited service users cannot invest large amounts of money with only a slight guarantee of return on investments. (2) the cultural model in sub-saharan African can be leveraged in various ways to implement alternate services with different organization paradigms. In previous work, for example, we have shown how opportunistic networking, while being mostly an academic subject in the west would be widely accepted in Sub-Saharan Africa [7].

A shift in the paradigm of sensing. Because data links are not pervasive in developing countries so that an internet of things might create an ambient environment where information is seamlessly pushed from sensors to users, we propose to make the user actively participate in the sensing tasks. In most developing countries, users will readily take part and even become a "sensor" for his surroundings. Thus, if we consider the NFC technology which, despite large mediatization, has not yet been (completely) successful in developing countries [10], we could envision many services in Africa that will build on it to implement smart cities: users holding NFC-enabled feature phones can be willing to move to the sensor and interact with it. Feature phones are now available at very low cost, and China exports towards Africa millions of Android smartphones that people can easily afford. The capabilities of these phones however are not even slightly exploited, since there are no content available through an expensive bandwidth. Implementing new dedicated services for smart cities may help users benefit from the potential of their devices and make their money worth.

Opportunistic delivery of information. In the absence of centrally powered infrastructures to sprinkle information on users in a top-down fashion, peer-to-peer connections must be favored for an horizontal information sharing. In the context of sub-saharan Africa, the cultural model can be leveraged to implement opportunistic networking schemes that will allow to setup user-powered smart-cities. In this context indeed, *individualism* has not yet emerged and people are less concerned with other aspects, such as privacy, which hinder various innovations in developed countries. Although, we do not claim that privacy is not an important issue, we not that, so far, it is perceived differently in Africa.

4.2 Possible solutions for the case studies

To make more concrete the ideas in this position paper, we propose schemes for implementing smart city services in the context of Ouagadougou to solve the challenges described in previous section in public transportation and health care.

SMS+NFC: A killer combination for bus schedules. The momentum of SMS-based services in Africa is beyond expectations, and many ICT4D solutions leverage SMS in their implementation [3]. For bringing near real-time information on bus positions in the traffic and the wait time to commuters, we propose an SMS-based service. To trigger SMS automatic sending however, we rely on the NFC technology which is now available in many low-cost devices.

In the proposed setting illustrated in Figure 3, a mobile phone, stripped down to its bare essential of "SMS sender" is embedded in the information backboard of each bus stop. Each of such phones is able to receive an SMS that it can parse to extract some information, and can also send SMS messages, in a predefined format, to commuters. The process is as follows: when a bus arrives at a station (1), an SMS is sent to the current and next stations of the bus service line. The SMS is sent from a mobile phone linked to the door of the bus, or following an activation by the driver. The sent message includes information on the current location of the bus, and a timestamp. We could imagine future scenarios where information on the state of occupation of the bus is also included to warn commuters to search for alternatives. Once the SMS is received at a bus station it is processed and used to updated obsolete information. A user arriving at a bus stop (2) may now request to know if a bus is coming and where it is currently (i.e., how many stations, probable time, etc.). To that end he approaches his NFC-enabled phone to the backboard to initiate a communication via SMS. This communication, during which the user's phone number was

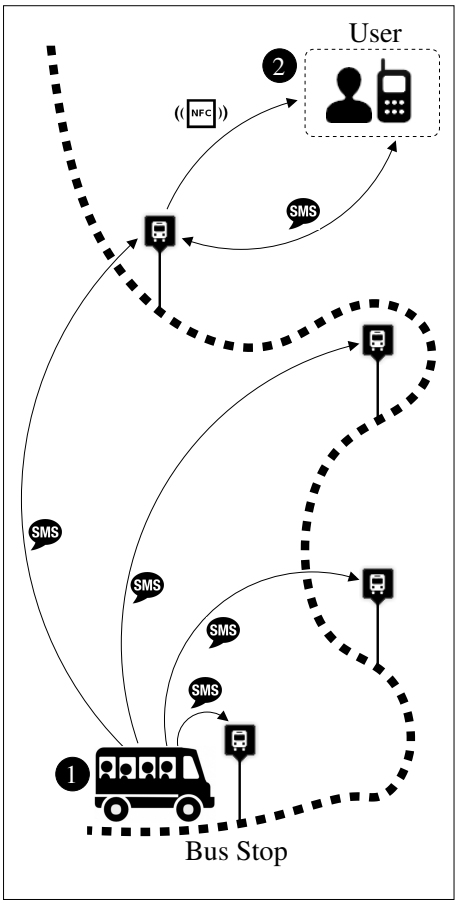


Figure 3: Keeping Commuters up-to-date on bus passage timetables

communicated to the phone embedded in the backboard, will trigger the sending of an SMS from the backboard to user's phone with the necessary information.

Collaborative tracking of drug stocks across the city. To keep track of drug availabilities across the city, patients and doctors cannot trust pharmacy owners to keep them updated anywhere any time. However, it is in their interest that people who come by their stores always find what they need: not finding a product once or twice in the same drugstore may deter people to come back in the future. Given that, as suggested before, people in undeveloped countries are willing to do a small effort to participate in the realisation of services, we propose a collaborative where patients (or at least any client of a drugstore) can share information on drug stocks. Because drug availabilities can become a life or death issue, we believe that it is reasonable to request that public authority finance a SMS platform to scale the processing of SMS messages.

Figure 4 illustrates the proposed scheme. On the facade of a given pharmacy, two NFC tags are placed, each containing information to identify and locate the drug store. When a user requests a drug in the pharmacy and is served (or not) he taps (1), on his way out, his phone against the right tag: one tag is for when he has found the drug and the other is when he has not. The SMS application in his phone is then triggered and a pre-filled message is composed. He must now enter a name, reference, or any information he wishes to define the drug he was looking for. The SMS is then sent to the platform which processes it to extract and consolidate this information with data from other users.

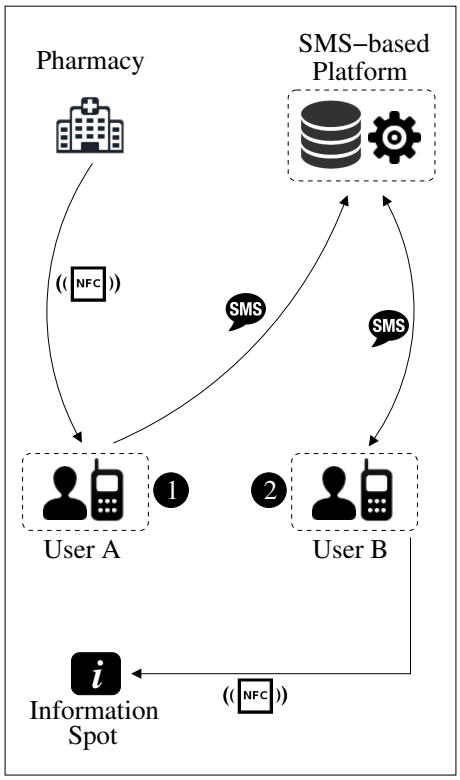


Figure 4: Collaborative knowledge on drug availabilities in pharmacies

Let us consider the second case where a user wishes to quickly locate (2) a pharmacy selling a specific drug. He goes to an information spot, which could be located within the hospital, or within pharmacies, and then tap his phone against it. This will trigger the SMS application with a prefilled SMS to which the user adds a name for the drug he is seeking. The SMS is then sent to the platform which, based on processed information in its database, will send back to the user a ranked list of pharmacies.

5. DISCUSSIONS

The proposed solutions are preliminary ideas for implementation smart cities in the least developed countries. We propose to build on the widespread acceptance of SMS-based services as well as the cultural model, and on low cost of NFC-enabled devices. The approach further yields a novel scheme for sensing in urban technological deserts, opening new engineering and business directions for ICT4D implementations.

There are still many technical challenges in the proposed approaches for the case studies of this paper. For example, hiding mobile phones in a backboard at a bus station to prevent people from stealing it is a small challenge if it

must be done locally to minimize the costs of an off-the-shelf solution.

There are also research opportunities on e.g., natural language processing for the SMS platform to "identify" the name of drug written by the user and which can contain a typos, and can also be written as it is pronounce in the mother tongue of the user.

6. CONCLUSION

In the context of mobile services to deploy within smart cities, we have presented the basis of a (realistic) approach to support sensing in urban technological deserts such as the regions of sub-Saharan Africa. This approach is based on the fact that "cheap" technologies (SMS, NFC) must be used and it leverages the organization of the society in which encounters and exchanges between people provide the opportunity to apply the concepts of opportunistic networking. Indeed, SMS-based communication is widespread (as it is not always affordable to access 3G or 4G networks when there are deployed) and the use of the NFC technology generates no additional costs for the citizens. In addition, the personal experiences on how people regroup and stay very long close just for greeting each other offer a framework to exploit in establishing reliable P2P connections (with adapted mobile devices) for publishing collected information (useful for other peers). In other terms, each individual becomes a "sensor" for his surroundings. The proposed approach also relies on the fact that the sensing paradigm can change because the people in the targeted areas are more willing to participate to the process. The cultural model leads the people to be more active in the sensing operations and to reach the source of information (even if it requires an effort on their parts).
These elements encourage us to continue our work in identifying the most relevant element to consider in implementing the concept of ICT-based smart cities (with mobile e-services) in sub-Saharan Africa. In the next steps, we plan to propose the complete definition and the evaluation of a mobile service intended to improve the experience of users regarding the provision of bus hours and traffic information in the public transportation system of Ouagadougou (Burkina Faso).

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