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IoT, An Affordable Technology to Empower Africans Addressing Needs in Africa

Philippe COUSIN[1], Charlotte DUPONT[1], Sabrine FATNASSI[1], Congduc PHAM[2], Ousmane THIARE[3], Amos WUSSAH[4], Sename KOFFI[5]
[1]Easy Global Market, 2000 route des lucioles, Sophia Antipolis, 06901, France
Tel: +33982330672, Email: (name.surname)@eglobalmark.com
[2]Université Pau Pays de l'Adour, Avenue de L'université, Pau, 64000, France
Tel: + 33 5 59 40 70 00, Email: congduc.pham@univ-pau.fr
[3]University Gaston Berger, Saint-Louis, BP.234, Senegal
Tel: +221 33 961 2340, Email: ousmane.thiare@ugb.edu.sn
[4]Farmerline ltd, Prof Sir Acheampong Street, Kumasi, Ghana
Tel: +233242141333, Email: amos@farmerline.org
[5]L'africaine d'architecture-Woelab, 209 Rue Kala, Lomé, Togo
Tel: +228 93540826, Email: sename@lafricainedarchitecture.com

Abstract: The opportunity for ICT intervention in Africa is huge especially for the so-called Internet of Things (IoT). The paper presents the EU-Africa H2020 WAZIUP project which focuses on IoT and related big data management for African applications. It takes cost of hardware and services as the main challenge to be addressed. The paper describes our proposed low-cost and open IoT gateway and platform for both robust and simple deployment and present real applications for Africa. The project involves African innovation hubs which help to stimulate innovation and empower African to help solving problems in Africa.

Keywords: Long-range IoT, low-cost deployment, Sub-Saharan Africa applications, African innovations

1. Introduction

1.1 Africa is Facing Challenges in Cities and Rural Areas and Need Efficient Solutions

New report [1] presented by the UN Development Programme (UNDP) has reported that, with two-thirds of Africans expected to live in cities by 2050, how Africa urbanises will be critical to the continent's future growth and development. "African countries, which include top worldwide growth champions, have shown remarkable resilience in the face of global economic adversity. Turning Africa's steady resilience into better lives for Africans requires strong policy action to promote faster and more inclusive growth," stated Abebe Shimeles, Acting Director, Development Research Department, at the African Development Bank. The continent is urbanising at a historically rapid pace, coupled with an unprecedented demographic boom, with the population living in cities doubling from 1995 to 472 million in 2015

Another issue to take into account is that about 64% of the population of Sub-Saharan Africa is living outside cities. The region will be predominantly rural for at least another generation. The pace of urbanization here is slower compared to other continents, and the rural population is expected to grow until 2045. The majority of rural residents manage on less than few Euros per day. Rural development is particularly imperative in sub-Saharan Africa, where half of the rural people are dependANT on the agriculture/micro and small farm business, other half faces rare formal employment and pervasive unemployment. For

rural development, technologies have to support several key application sectors like living quality, health, agriculture, climate changes, and has to overcome both technical challenges as well as economical challenges.

1.2 Internet of Things as a Powerful and Affordable Solutions to Cope with Societal Challenges

The opportunity for ICT intervention in Africa, to help solving problems, is huge especially for the so-called Internet of Things (IoT). It is widely accepted that the Era of IoT can potentially connect billions of sensors, devices, equipment, systems, etc. In turn, the challenge is about driving business outcomes, consumer benefits, and the creation of new value. The new mantras for the IoT Era are becoming collection, convergence and exploitation of data. The information collection involves data from sensors, devices, gateways, edge equipment and networks on to their respective siloed IoT platforms in order to increase process efficiency through automation & optimization while reducing downtime and improving people productivity, see Figure 1(right). Figure 1(left) depicts some typical applications where real-time data collection could greatly increase quality and productivity.

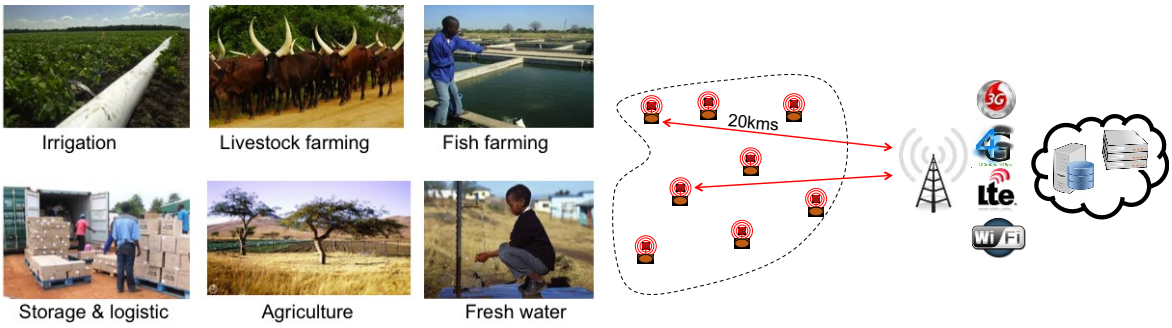

Figure 1: Left: Some ICT fields of opportunities. Right: Long-range 1-hop connectivity

Over the last several years there has been a lot of discussion and research on IoT to understand the reference architecture and what is IoT and how it can impact our daily life. It is not a question any more on whether IoT will come or not: most of the companies have already defined internal business activities to go along with this global move. However, when developed countries discuss about massive deployment of IoT, Africa's countries, particularly in Sub-Saharan Africa, are still far from being ready to enjoy the full benefit of IoT. This is because of many challenges: lack of infrastructure, high cost platforms, complexity in deployment, etc.

The rest of the article is organized as follows. Section 2 presents the EU-Africa cooperation in IoT and Big Data with the Waziup project. In Section 3 we will present the clear objectives of the cooperation. Section 4 describes briefly the end-device part of the project where along with low-cost gateway, low-cost and generic IoT/sensor platforms will be provided. Section 5 introduces the real developments and section 6 and 7 provide business benefits and conclusion.

2. Solutions with an Open Environment: the WAZIUP Platform

To help providing affordable and efficient solutions, on 1st February 2016, a 3-years EU project called WAZIUP (www.waziup.eu) was funded under the EU H2020 programme within the specific topic of cooperation between EU and sub-Sahara countries. WAZIUP is a collaborative research project using cutting edge technological research applications on IoT and related big data management and advanced analytic issues. The project brings liaison with the whole IoT European Research Cluster (IERC) and leading research and

development organizations in Africa. The project is driven by a consortium of 5 EU partners and of 7 African partners from 4 sub-Saharan African countries.

3. Objectives

WAZIUP will have clear objectives to:

1. Develop low cost solutions as demonstrators to show how to efficiently solve some problems in Africa such as cattle rusting, climate change effects, urban waste management, just to mention few ones.
2. Provide DIY (Do-It-Yourself [5]) development kit to African communities to empower them to solve problems in their country
3. Engage African software developers community and innovation hubs to support development of key applications. Tutorials are available on line
4. Stimulate entrepreneurship and create start-ups (ie objective is to create at least 10 start-ups) . Hackatons are organised and the project should target 15 sub-Saharan countries

WAZIUP is providing ICT solutions to address the following global results:

1. Give **rural Access to Technology:** Vast distances and poor infrastructure isolate rural areas, leaving those who live there poorly integrated into modern ICT ecosystems. WAZIUP will offer the long-range IoT communication network to connect rural communities: the software service platform will offer highly innovative monitoring, recommendation, notification services based on the data coming from multiple rural application sectors.
2. Drastically reduce **cost of hardware and services:** Power consumption and deployment costs are the two most important issues for devices: the first issues are universal for IoT and the later one is more specific to Sub-Sahara Africa. High delivery and infrastructure costs discourage service providers from reaching the countryside. The potential of IoT, in Sub-Saharan Africa, can only be realized if the cost is resolvable as most of the rural population in the Africa is at the poverty level.
3. **Solve a lot of Africa problems by empowering African communities and entrepreneurs:** there are a lot of problems to solve either in rural or urban areas. With a low cost and efficient solutions powered by advanced software African local entrepreneurs, coders can provide sustainable and cost-effective solutions. Doing this will help also to provide key training in important new technologies.

4. Technology Description

4.1 LoRa the Long-Range-Low Energy Technology for IoT and Useful for Africa

One important issue is the lack of energy and network in many Africa areas. The new technology called LORA[2] allows providing long-range communication on low energy meaning using simple batteries. Semtech's [3]long-range technology (called LoRa) belongs to the spread spectrum approaches where data can be spread in both frequencies and time to increase robustness and reception range to several kilometres while keeping power consumption very low for battery-operated devices as opposed to GSM/2G connectivity. As shown previously in figure 1 (right) the deployment of a LoRa network is centred on a gateway that usually has Internet connectivity. This architecture greatly simplifies IoT deployment compared to multi-hop short-range technologies, thus enabling low-cost large-scale deployment scenarios.

4.2 Developing IoT/sensor at Very Low Cost

WAZIUP fully takes the "Arduino" philosophy for low-cost, simple-to-program yet efficient hardware platforms. These features are clearly important issues to take into

account in the context of developing countries, with the additional benefit that due to their success, they can be acquired and purchased quite easily worldwide. There are various board types that can be used depending on the application and the deployment constraints and we support most of them. However, the Arduino Pro Mini, which comes in a small form factor and is available in a 3.3v and 8MHz version for lower power consumption, appears to be the development board of choice to provide a generic IoT platform. It can be purchased for less than 2 euro a piece from Chinese manufacturers.

WAZIUP develops and integrated building blocks for quick and easy new behaviour customization and physical sensor integration as shown in Figure 2 (left). Building blocks are security, transmission, activity & physical sensor management. Integration of new physical sensor can be realized without modifying the core template. Figure 2 (right) shows a beacon-collar device for cattle rustling application where the presence of a cow can be deduced from both reception of periodic beacons and the received signal strength (RSSI).

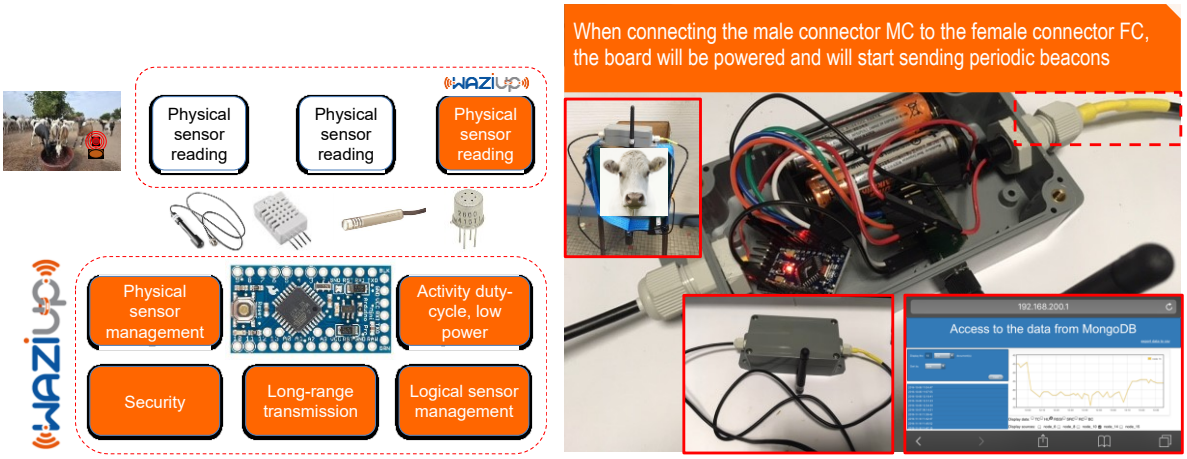

Figure 2: Left: Generic low-cost IoT platform. Right: a simple beacon collar for cattle rustling

4.3 Developing Low-cost Gateway

In the context of the WAZIUP project, which focuses on developing countries, it is important to keep both the cost and the complexity of the gateway low, targeting small to medium size deployment scenarios for specific use cases. The proposed low-cost LoRa gateway listen on a unique frequency channel and runs on a Raspberry™ PI. The total cost of the gateway is as low as 45 euro with the radio module included.

The added value of the proposed low-cost gateway resides in its high modularity and flexibility for fast customization and appropriation. Advanced data post-processing tasks are performed after the gateway stage by using Unix redirection of gateway's outputs as shown by the orange "post-processing" block in figure 3(middle). We promote the usage of high-level language such as Python or Go to implement all the data post-processing tasks such as access to IoT cloud platforms and even AES decryption features. Our gateway is distributed with Python templates showing how to upload data on various IoT cloud platforms. Examples include Dropbox™, Firebase™, ThingSpeak™, freeboard™, SensorCloud™, GrooveStream™ & FiWare as illustrated in figure 3(right).

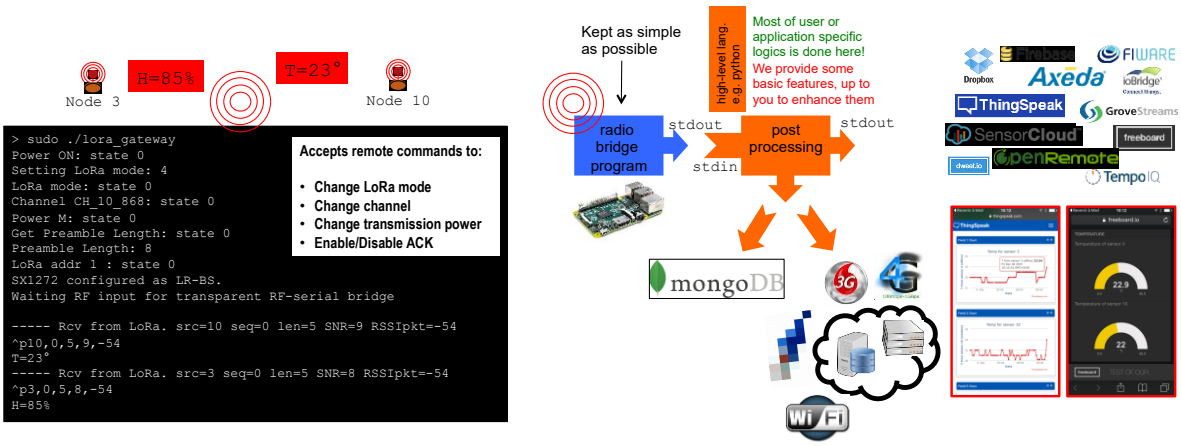

Figure 3: Low-cost gateway architecture and templates for various IoT clouds for out-of-the-box deployment

4.4 Gateway Running without Internet Access

One additional important issue that need to be taken into account for WAZIUP is the lack or intermittent access to the Internet. In all cases, data are locally stored on the gateway and the latter can be directly used as an end computer by just attaching a keyboard and a display. This solution perfectly suits low-income countries where many parts can be found in second markets. The gateway can also interact with the end-users' smartphone through WiFi or Bluetooth. In Figure 3, the RSSI graph is actually plotted by the gateway running a local web server linked to the local database. For cattle rustling applications in remote areas, the whole system can be deployed in a fully autonomous manner.

4.5 The Overall IoT Architecture

Beyond deployment of IoT and gateways, complex applications need to rely on a well define architecture. The overall architecture defined in Waziup is divided into three sections: The top most block represents the Cloud platform, the middle one is the network connectivity while the bottom one is the local deployment including gateway and sensors.

For the local deployment, we will use low cost devices and gateways. The connectivity between the device and the gateway will be based on LoRa technology described in 4.1. The end device will be low cost (based on Arduino) and for some use cases it will have an energy harvesting module based on a solar panel to overcome Africa's energy issues.

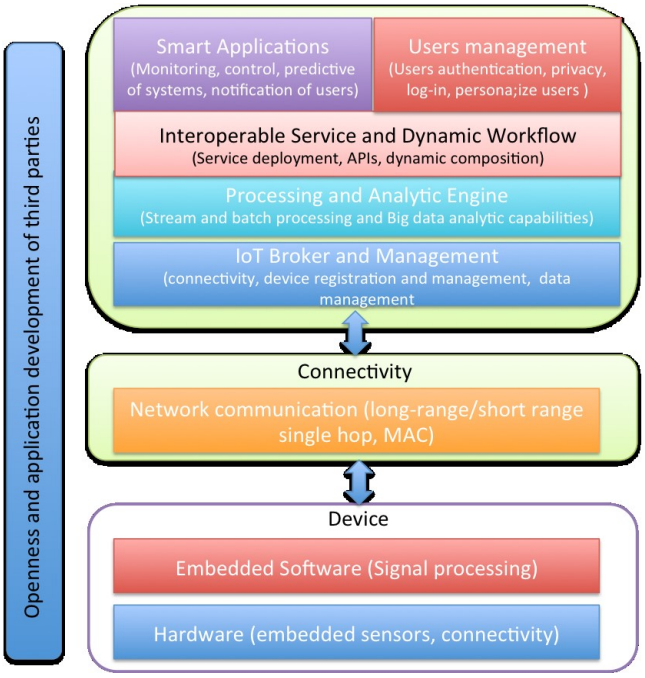

Figure 4: Functional overview

For the gateway as stated in 4.3, it will ensure a secure bidirectional communication between the IoT devices and the cloud. For the cloud layer, it will include an IoT platform and a big data platform. The IoT platform is based on an IoT Broker handling the big and various amounts of data and providing the needed abstraction for the users via the NGSI API. The IoT platform will also provide the remote management of gateway and devices.

5. Developments and Innovation Support

5.1 The Minimum Viable Iroducts (MVP) Approach

WAZIUP project will not aim to deliver academic results but solid and tangible products or technical and business toolkits to do them. Coming from the (lean) start-up method, the project will implement the Minimum Viable Product (MVP) [4] approach. A minimum viable product has just those core features sufficient to deploy the product, and no more. Developers typically deploy the product to a subset of possible customers—such as early adopters thought to be more forgiving, more likely to give feedback, and able to grasp a product vision from an early prototype or marketing information. This strategy targets avoiding building products that customers do not want and seeks to maximize information about the customer per money spent. The MVP is part of a strategy and process directed toward making and selling a "waziup stimulated" product to customers. The project is currently working on few MVPs with a development cycle of version every 6 months.

5.2 Example of the Waziup Prototype (MVP) for Fish Farming in Ghana

In Ghana, the combination of the annual supply of fish from capture and from aquaculture doesn't meet half of the country demand. The need for fish importation is thus very important. This shortage in supply is expected to increase further with limited prospects for increasing marine and inland fisheries. Aquaculture has thus become pivotal in the future development of the fisheries sector in Ghana.

The Ghanaian aquaculture is a small but diverse sector characterized by small to large scale cage aquaculture and small scale pond aquaculture. Aquaculture in Ghana is in its developmental stage and shows a lot of promise. Aquaculture is currently practiced in all 10 regions of Ghana, most prominently in the southern and central belts. Annual production is reported to have risen from 7,154 metric tons in 2009 to 27,451 metric tons in 2014.

Water quality is a term that reflects the overall ability of culture water to provide optimal growth conditions for the fish species of interest. Water quality is the first most important limiting factor in pond fish production yet it is the most difficult production factor to understand, predict and manage. Water quality conditions in a pond are controlled by both natural processes and human influences. Its quality directly affects feeding efficiency, growth rates, the fish's health and survival and consequently production yields and profit of the farmer. Most fish kills, disease outbreaks, poor growth, poor feed conversion efficiency and similar management problems are directly related to poor water quality. To deal with the water quality issues, WAZIUP will help farmers to monitor their fishponds by implementing low-cost sensors and low-cost gateway. Data will be pushed on WAZIUP platform and the farmers will get SMS notifications if the values fall out of the normal range. They will also be able to monitor the water quality data directly on internet dashboard and to proceed to complex analysis and comparison of all the measured parameters. The first implementation will take place in Kumah Farms, in Kumasi, Ghana. Kumah Farms manage 18 fish farming ponds of various sizes, from 120 m² to 0.8 hectares.

The first version of the monitoring device will be a buoy, floating on the pond, with low-cost temperature, pH and dissolved oxygen sensors 30cm below. The buoy will be fixed on a pipe inside the pond, in a manner that it can goes up and down with water level variation. Indeed, the water level varies a lot in this outside pond configuration and the fish can even escape from the pond during the rainy season.


Figure 5 & 6: The prototype low cost buoy and its deployment in fish farm at Kumasi, Ghana

In the future versions of the device, more low-cost sensors will be added (alkalinity, ammonia and turbidity). The buoy will also be improved with locally made material and more ponds will be monitored.

5.3 The Innovation Hubs

Thanks to African innovation hubs partners of WAZIUP, we will organise many innovations related events such as Hackatons to stimulate African innovations in using Waziup solutions. 1st Hackaton called WAZIhack organised 14-15 December 2016 in Dakar has already be a success with 24 projects presented with few already prototypes. 3 projects were selected by a jury for further actions. Next events are now planned end February 2017 in Ghana and Togo. Also some star-ups are working on Waziup cases such as a start-up called LIZI incubated and supported by the Woelab-Fablab in Lomé, Togo.

5.4 Results

WAZIUP has already identified some applications to bring innovation in certain domains in rural context. Some surveys to the end-users have been done on identified use cases of these applications. According to the analysis we did on the results of these surveys we selected some of use cases to be implemented on the test-bed. Some applications are selected: precision agriculture, cattle rustling, and fish farming. We describe below these applications.

Precision agriculture: the Testbed set up in UGB in Senegal will explore the ability of IoT technology to improve crop management, through increased production (yield), lower operational costs plus smarter applications of chemicals and fertilizers. This trial will focus on improving crop yield through the analysis of real-time data from a variety of environmental sensors and other sources of truth located in commercial crop fields or throughout the enterprise. The goal here is to obtain and produce weather related information which will be used to advise the farmers on how to proceed to increase the productivity or to prevent any disaster scenario. In order to carry out this trial, UGB already has an area allocated to the WAZIUP project, on its farm.

Cattle Rustling: this goal of this application is to give critical information about cattle to the farmers in order to prevent the cattle theft.

The solution is to deploy LoRa end devices on animals. The information gathered by LoRa end devices will be sent to a gateway that will notify the farmer about critical situations. Information that will be provided to the farmer are: position, and speed.

Figure 7: Left: The cow collar under development. Right: The deployment field

This trial will be carried out in a national breeding centre located 6km from the UGB.

6. Business Benefits

IoT allow businesses to be smarter with real-time operational insights while reducing operating costs. WAZIUP focus on long-range IoT communication network to connect rural communities, low power consumption and deployment costs devices will go a long way to revolutionize and enhance the development of IoT solutions for rural Africa. The integrated approach will provide the tools to enable rural people and farmers to enter directly into new vertical communication relationships with external agencies to improve the quality and relevance of information resources such weather predictions and water quality.

WAZIUP is including predictive analytics and real-time diagnostics to drive down the maintenance costs. All this will help address the real needs of the local community of users.

At the end, Waziup intends to stimulate local economies in a broad range of domains (eg productivity in fish farming, water saving in irrigation, crop production ..) but even more, than to African incubators, help to create start-ups which hope to create new business and new jobs.

7. Conclusions

First Hackatons made evident on the potential of innovation and the interest expressed by African start ups and innovators to use such open and low cost solutions to address a broad range of domains (e.g. agriculture, waste management, fish farming, health, logistic, etc.) Waziup will have 2 more years with many interactions with users and developers to improve the technical offers and the current prototypes (MVPs) to let at the end useful and efficient solutions to empower African start-ups and developers to solve African needs while developing businesses and economics activities.

At the end, Waziup intends to stimulate local economies in a broad range of domains (eg productivity in fish farming, water saving in irrigation, crop production ..) but even more, than to African incubators, help to create start-ups which hope to create new business and new jobs.

References

[1] AfDB/OECD/UNDP (2016), African Economic Outlook 2016: Sustainable Cities and Structural Transformation, OECD Publishing, Paris. http://dx.doi.org/10.1787/aeo-2016-en

[2] LoRa Alliance, “LoraWAN specification, v1.0,” 2015.

[3] Semtech, Jeff McKeown, “LoRaTM- a communications solution for emerging LPWAN, LPHAN and industrial sensing & iot applications. http://cwbackoffice.co.uk/docs/jeff 20mckeown.pdf”, accessed 13/01/2016.

[4] Ries, Eric (August 3, 2009). "Minimum Viable Product: a guide" http://www.startuplessonslearned.com/2009/08/minimum-viable-product-guide.html

[5] C. Pham, “A DIY low-cost LoRa gateway. http://cpham.perso.univ-pau.fr/lora/rpigateway.html”, accessed 13/01/2016.