PART V

INTERNATIONAL COLLABORATION
on Research and Experimentation

24

WAZIUP: Open Innovation Platform for IoT-Big Data in Sub-Sahara Africa

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24.1 Introduction

ICT developments in Sub-Saharan Africa has the potential to cut across traditional sectors: notable examples are the introduction of micro-health insurance and health-savings accounts through mobile devices; index-based crop insurance; crowd-sourcing to monitor and manage the delivery of public services. These innovative applications recognize and leverage commonalities between sectors, blur traditional lines, and open up a new field of opportunities. The opportunity for ICT intervention in Africa is huge especially of IoT and big data: those technologies are promising a big wave of innovation for our daily life. The era of IoT can connect billions of sensors, devices, equipment, systems. In turn, the challenge is about driving business outcomes, consumer benefits, and the creation of new value. The new mantras for the IoT era is the collection, convergence and exploitation of data. The information collection involves data from sensors, devices, gateways, edge equipment and networks. This information allows increasing process efficiency through automation while reducing downtime and improving people productivity. The WAZIUP project will show:

Potential of IoT and Big data in Africa: Over the last several years there has been a lot of discussion and research on IoT to understand the reference architecture, what is IoT and how it can impact our daily life. It is not a question any more on whether IoT and big data will come or not: most of the companies have defined internal business activities to go along with this global move. According to the EC nearly five billion things will be connected by 2015, reaching 25 billion by 2020, helping citizens save energy, reduce traffic jams, increase comfort, and get better healthcare and increased independence. Revenues in the European Union from IoT are estimated to represent €400 million in 2015 and are set to increase to more than €1 trillion by 2020. However, countries in Sub-Saharan Africa are still far from being ready to enjoy the full benefit of IoT. This is because of many challenges, such as lack of infrastructure, high cost platforms and complexity in deployment. At the same time, it is very urgent to promote IoT worldwide: WAZIUP will contribute by reducing part of the technology gap between EU and Africa. Thus, the goal of WAZIUP is to deploy and validate real-life IoT and big data pilot cases with several Sub-Saharan African countries.

There are two key reasons why IoT and Big Data should be addressed now in Africa.

- *For EU*: to create critical mass within the IoT innovation ecosystem and facilitate co-creation of products and services in open ecosystems; to this respect, it is necessary to be cooperative with Africa. As the continent has full of young talent (more than 40% of the population in sub-Saharan countries is younger than 15 years old), the cooperation on IoT and Big data with Africa will boost the economy for both continent;
- *For Africa*: There are many challenges to the adoption of IoT and Big Data in Africa. This is why WAZIUP is conceived as a pathfinder project for Africa. We believe that the technological landscape in Africa can move very fast, it is hence urgent to promote the WAZIUP technologies in Africa and to harmonize with global IoT and Big Data movement in order to better prepare for the upcoming ICT wave.

The reason why WAZIUP targets the rural community in Sub-Saharan Africa is because about 64% of the population 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 depending 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, etc. To reach WAZIUP goal, one has to overcome both technical challenges as well as economical challenges. WAZIUP project consider how to best design and deploy the IoT-Big Data technology considering cost and energy challenges in the first place. WAZIUP will target the removal of three major barriers:

- *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 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.
- *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-Shahara 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. WAZIUP will take this challenge as the main one to be addressed. WAZIUP will also consider power consumption: devices must reduce the overall power consumption. However the deployment challenges cannot only be realized by reducing the devices as well as service costs, let alone to reduce the joint cost of the devices and service: there has to be an innovative business model. We envision mostly spin-offs enterprises for micro-small scale services that could afford to rent the devices to farmers and provide them services. In this case the cost of services must be also affordable. Hence WAZIUP will have a dedicated effort to design a viable exploitation model which may lead to the creation of small-scale innovative service companies.
- *Quality of service*: the technology of WAZIUP can be used to overcome a structural problem in the work market in Africa: very often communities located in isolated areas are left behind in the innovation process not because they are unwilling to benefit from changes in the technology, but rather because by definition those areas attract fewer and less qualified professionals, civil servants, skilled workers, and innovators than urban centers. Having a technology which offers remote assistance and control indeed greatly mitigates such effect of marginalization. Furthermore, some of the advanced intelligent services, e.g., those qualified as "watch-dog" applications – as in the case of cattle-rustling prevention – have the role of increasing security and/or reliability in remote locations and thus

have the potential to increase the general quality of experience in the usage of ICT solutions.

Beside the cost and power consumption, the robustness of hardware is a core requirement: hardware has to be robust enough so as to require lower maintenance and handle environmental and deployment threats as well. WAZIUP will collect the grand challenge: reduce costs, reduce power consumption but at the same time increase the robustness of the hardware. WAZIUP will bring in existing IoT-Cloud and big data platform developed in several EU as well as industrial projects. The technologies will address the specific needs and conditions of the business use case identified in the projects.

24.2 Objective

WAZIUP is a H2020 international cooperation action. The project is driven by a consortium of 5 EU partners and of 7 partners from 4 sub-Saharan African countries. Furthermore, it has support from multiple African stakeholders with the aim of defining new innovation space to advance the African Rural Economy. It will do so by involving end-users communities in the loop, namely rural African communities of selected pilots, and by involving relevant public bodies in the project development. WAZIUP will accelerate innovation in Africa by coupling with current EU innovation in the sector of IoT and Big Data: this EU technology will be specialized to generate African cost effective technologies with an eye to preparing the playground to the future technological waves by solving concrete current needs. WAZIUP will deliver a communication and big data application platform and generate locally the know how by training by use case and examples. The use of standards will help to create an interoperable platform, fully open source, oriented to radically new paradigms for innovative application/services delivery. WAZIUP is driven by the following visions:

- *Empower the African Rural Economy*. Develop new technological enablers to empower the African rural economy now threatened by the concurrent action of rapid urbanization and of climate change. WAZIUP technologies can support the necessary services and infrastructures to launch agriculture and breeding on a new scale;
- *Serve the Wealth Growth of Rural Communities.* Create innovation across a dated agribusiness/agriculture/rural sector: increasing agriculture's value and by adding to sub-saharan countries economical growth, such innovation contributes towards poverty reduction of communities living in the rural areas;

- *Innovate Agro-Industry Processes.* Increase efficiency of production and processing in small-scale agro-industry SMEs, catalyze better yields and advance agribusiness;
- *Improve work conditions.* WAZIUP technology aims at improving work and living quality by affordable and available specific IoT services tailored for African rural communities;
- *Tailored IoT and Big-data Technology.* Offer smart sensor and data-driven applications and services addressing the end-users needs and requirements (understanding users requirements and preference delivering towards more personalized and easy users interfaces and applications)
- *Value-added cost and energy efficiency.* IoT application and services based on WAZIUP open IoT-Big data platform will focus on ease of maintenance and low cost of solutions;
- *Lower Entry Level.* Provide to application developers a mature platform, as well as tools and standards that are inexpensive, easy and relevant.

In order to achieve the above aims, a strong dissemination and exploitation effort of the project will be dedicated to a) strengthening linkages of end-users with industries, b) engage innovation space and living labs to accelerate innovation coaching/training/start-up activities (e.g., community-driven development paradigms), c) promote value-addition to business outputs, d) challenge the value-chain of African agribusiness through technology for value increase.

The proposed solutions will be tested for a set of real-life use cases covering several countries. At higher level, WAZIUP will implement a regional innovation platform, where SMEs could continue to develop/plug-in solutions using the technical elements and the open data provided in the project. The ultimate target is to create large African industries, SMEs ecosystem, and induce a network-effect.

The above objectives require tackling several challenges which we enlist below:

- *Challenge 1: Innovative design of the IoT platform for the Rural Ecosystem.* Low-cost, generic building blocks for maximum adaptation to end-applications in the context of the rural economy in developing countries.
- *Challenge 2: Network Management*. Facilitate IoT communication and network deployment. Lower cost solutions compared to state of the art technology: privilege price and single hop dedicated communication networks, energy autonomous, with low maintenance costs and long lasting operations.

- *Challenge 3: Long distance*. Dynamic management of long range connectivity (e.g., cope with network & service fluctuations), provide devices identification, abstraction/virtualization of devices, communication and network resources optimization.
- *Challenge 4: Big-data*. Exploit the potential of big-data applications in the specific rural context.

From a technical standpoint, WAZIUP introduces innovation by constructing on the following pillars of IoT/Big Data technology, specifically tailored for the rural ecosystem:

- *Privacy and security*: through attention to all related privacy and security aspects with specifics addressing the involved communities (farmers, developers);
- *Personalized and user friendliness*: models will receive requirements from users' needs and will ensure compliance with all most common usability standards (e.g., Web Accessibility Initiative – WAI or ISO/TR 16982:2002);
- *An Open interoperable platform*: through open standard and protocols from the Geospatial Consortium (OGC), W3C, IEEE from the European SDOs (CEN, CENELEC and ETSI, etc.) for all its key technology;
- *Continued Openness:* through the release of open specification and open software components and/or algorithms;
- *Low-cost and low-energy consumption*: through the design of innovation hardware (sensors/actuators), and of IoT communication & network infrastructure.

24.3 Technical Solution

In WAZIUP the challenges outlined above will be tackled using an open IoT-big data platform with affordable sensors connected through an IoT-Cloud open platform. This platform will also make use of mobile phones and real-time processing to empower users and deliver the needed services. Hereafter a compact list of core technical functionalities encompassed by the platform:

- Cloud-based real-time data collection combined with analytics and automation software: thus, the platform will offer cost-effective solutions for aggregating different machines and sensor types to engender efficiency, smart automation and optimization in the rural context.

- Intelligent analytics of sensor and device data: studied in order to optimize for performance of the rural workplace, detect potential outages, and finally reduce overall maintenance costs.
- Integration to 3rd parties' platform: enables customers' benefit of scaling fast and easy.
- PaaS (Platform-as-a-Service) provider: WAZIUP will provide to business clientele with independently maintained platform upon which their web application, services and mobile applications can be built.

The set of value-added services to be delivered by WAZIUP:
Long-distance real-time/near real-time monitoring and users notification: WAZIUP project enables the comprehensive monitoring of a product's condition, operation, and external environment through sensors and external data sources. By data processing, a product can alert users or others of changes in circumstances or performance. Monitoring also allows companies and customers to track a product's operating characteristics and history and to better understand the product's usage history. Usage history, in turn, may deeply depend on the specific rural communities involved.

Long-distance control of the system and devices: WAZIUP devices and platforms can be controlled through remote commands or algorithms that are built into the device or reside in the product cloud. Modern control techniques act through software embedded in the product or deployed in the cloud. This allows the customization of product performance to a degree that previously was not cost effective or often even possible. The same technology also enables users to control and personalize their interaction with the product in many new ways.

Optimization and big data analytic application: The rich flow of monitoring data from connected sensors/products, coupled with the capacity to control product operations, allows companies (SMEs, NGO) to optimize product performance in numerous ways, many of which have not been previously possible. WAZIUP project can apply algorithms and analytics to in-use or historical data to dramatically improve output, utilization, and efficiency of processes in the rural context. Real-time monitoring data on product condition and product control capability enables firms to optimize service by performing preventive maintenance when failure is imminent; they can also accomplish repairs remotely, thereby reducing product downtime and the need to dispatch repair personnel to remote rural areas.

24.4 Applications Cases

We present a detailed analysis of the different application cases selected for WAZIUP project, these are precision agriculture, cattle rustling, logistic & transport, fish farming and urban waste management.

24.4.1 Precision Agriculture

The goal of this application cases is to improve the working conditions and yield in the agricultural field by giving precise information on the ground status. To achieve this, we will gather data on the environmental conditions with dedicated sensors, analyze data and make optimized and personalized predictions for the farmers.

24.4.2 Cattle Rustling

Cattle rustling is a serious problem observed in African countries, particularly in Senegal. This is a recurring phenomenon that causes a lot of problems to farmers. Cattle's stealing is extremely expensive; it represents millions for farmers but also for the state annually. Faced with this problem, the famer is often helpless.

24.4.3 Logistics and Transport, Saint-Louis, Senegal

Whether by air, ground or sea, transportation and logistics are essential components to many enterprises' productivity, and access to real-time data is critical. Many industries and business sectors are struggling to grasp the possibilities of data-driven technology, but companies in transport and logistics are way ahead. By their very nature, the logistics providers that move objects by air, sea, rail, and ground have widely distributed networks and rely on rapid information about those networks to make decisions. As a result, they were quick to see the benefits of new sensor and connection technology, placing them at the forefront of the transition to a connected world.

24.4.4 Fish Farming, Kumasi, Ghana

In order to increase the management efficiency of the fish farms, this pilot will deploy a network of sensors to monitor remotely and in real time the water situation and quality within the fish ponds.

24.4.5 Environment and Urban Agriculture

African cities have the fastest urbanization speed of the world. Some cities like Kinshasa will have its population tripled by 2050. Thus, the African urbanity becomes the perfect experimental field to test urban smart systems. The most important challenges are the household living conditions improvement of food security, appropriate waste management and digitalization of the different sectors.

Table 24.1 is summarizing the uses cases that will be validated in the project.

24.5 WAZIUP Platform as a Service (PaaS)

Platform as a Service (PaaS) is a category of the cloud computing service that provides a platform allowing customers to develop, run, and manage applications; without the complexity of building the infrastructure typically associated with developing and deploying applications. Typically, a PaaS framework will compile an application from its source code, and then deploy it inside lightweight virtual machines or containers. This compilation and

Table 24.1 Pilot use cases

Application Domain	Use Cases
Precision agriculture	• UC1: Monitor soil • UC2: Field Weather Situation • UC3: Storage Moisture and Temperature
Cattle rustling	• UC1: Real-time position and itinerary of the cattle's herd • UC2: Ability to receive notification in critical situations
Logistics and transportation	• UC1: Track operations and remote monitoring • UC2: Real-time visibility across the supply chain • UC3: Check the integrity, identification, authentication and traceability of goods
Fish farming	• UC1: Fish Pond Water Quality • UC3: Cost-Efficient Feeding System
Environment and Urban agriculture	• UC1: Indoor/small scale farming automation • UC3: Confirm emptied waste bins

deployment is done with the help of a file called the manifest, which allows the developer to describe the configuration and resource needs for the application. The manifest file will also describe the services that the application requires and that the platform will need for provision. Furthermore, PaaS environments usually offer an interface for applications to scale up or down, or to schedule various tasks within the applications.

The idea of WAZIUP is to extend the paradigm of the PaaS to IoT. Developing an IoT Big Data application is a complex task. A lot of services need to be installed and configured, such as databases and complex event processing engines. Furthermore, it requires an advanced knowledge of the various communication protocols, the programming of embedded devices, the storage, processing and analysis of the data in a distributed fashion and finally the programming of GUIs and user interactions. The promise of the PaaS extended to IoT is to abstract away this work to a large extent.

Figure 24.1 shows the PaaS deployment in WAZIUP. Traditional PaaS environments are usually installed on top of IaaS (in blue in the picture). The blue boxes are physical servers, respectively the Cloud Controller and one Compute node. The PaaS environment is then installed inside the IaaS VMs, in green in the picture. We use Cloud Foundry as a PaaS framework. It comes with a certain number of build packs, which and programming languages compilers and runtime environments. It also provides a certain number of preinstalled services such as MongoDB or Apache Tomcat. The manifest file,

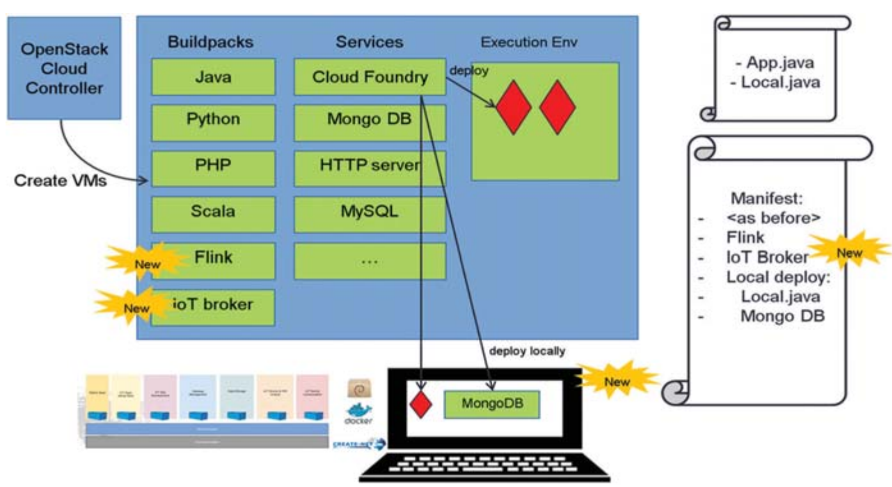

Figure 24.1 PaaS deployment extended for IoT in WAZIUP.

showed on the right hand side, provides a high-level language that allows describing which services to instantiate. We propose to extend this language to IoT and big data services such as:

- Data stream and message broker
- CEP engines
- Batch processing engines
- Data visualization engines

Furthermore, we propose to include in the manifest a description of the IoT sensors that are required by the application. This query includes data such as the sensor type, location and owner. The manifest also includes the configuration of the sensors. The application will then be deployed both in the global Cloud and in the local Cloud.

24.5.1 Local and Global Clouds

The WAZIUP project defines two different types of "Cloud": the local Cloud and the global Cloud. A local Cloud is an infrastructure able to deliver services to clients in a limited geographical area. The local Cloud replicates some of the features provided by the traditional Cloud. It is used for clients that may not have a good access to the traditional Cloud, or to provide additional processing power to local services. In order for such an infrastructure to be considered as a local Cloud it must support a virtualization technology. In the case of WAZIUP, the local Cloud comprises the end user or service provider PC and IoT Gateway. The local Cloud characteristics are:

- Existence of IoT devices attached
- Can have geographical characteristics
- Must support virtualization
- Must support local cloud components
- Has an identifiable administrator/owner
- Has certain regulations/privacy considerations for data access and treatment

The global Cloud, on the other end, is a "backbone infrastructure" which increases the business opportunities for service providers and allows services to access a virtually infinite amount of computing resources. In order for such an infrastructure to be considered as a global Cloud it must support a virtualization technology and be able to host the global cloud components of the WAZIUP architecture.

24.6 WAZIUP Architecture

This section provides the details of the WAZIUP architecture. A functional overview is given, followed by the actor definition, the components and finally the sequence diagrams.

24.6.1 Functional Overview

This section presents the functional view of the architecture.

Figure 24.2 shows the functional overview of WAZIUP. The topmost block represents the Cloud platform, the middle one is the network connectivity while the bottom one is the local deployment, including gateway and sensors. Table 24.2 shows the functional domains that have been identified, with a description for each of them.

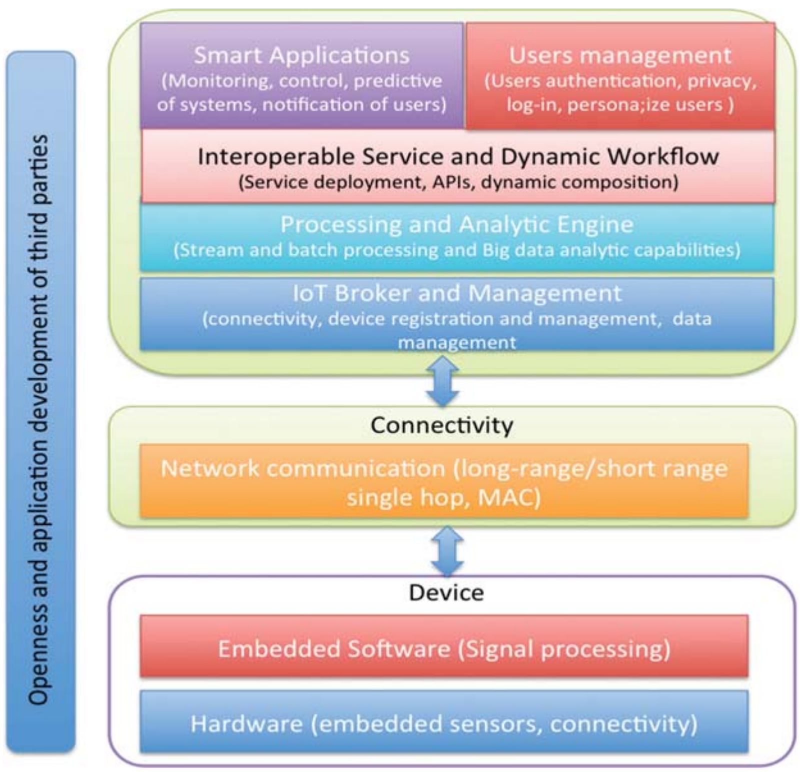

Figure 24.2 Functional overview of WAZIUP.

Table 24.2 Functional domains

Functional Domains	Description
Application platform	Application writing, deploying, hosting and execution.
IoT platform	The connectivity of IoT devices, the sensors data and metadata.
Stream and data analytic	Data brokering, stream processing and data analytics.
Security and privacy	Management of the identification, roles and connections of users. Also includes data anonymisation of the data and securisation of the transmissions.
Platform Management	Status of the components, deployment of the platform.

24.6.2 Components

Figure 24.3 presents the full WAZIUP architecture. It shows the four functional domains: Application Platform, IoT Platform, Security and Privacy and finally Stream & Data Analytic. The Application Platform involves the development of the application itself and its deployment in the Cloud and in the Gateway. A rapid application development (RAD) tool can be used, such as Node-Red. The user provides the source code of the application, together

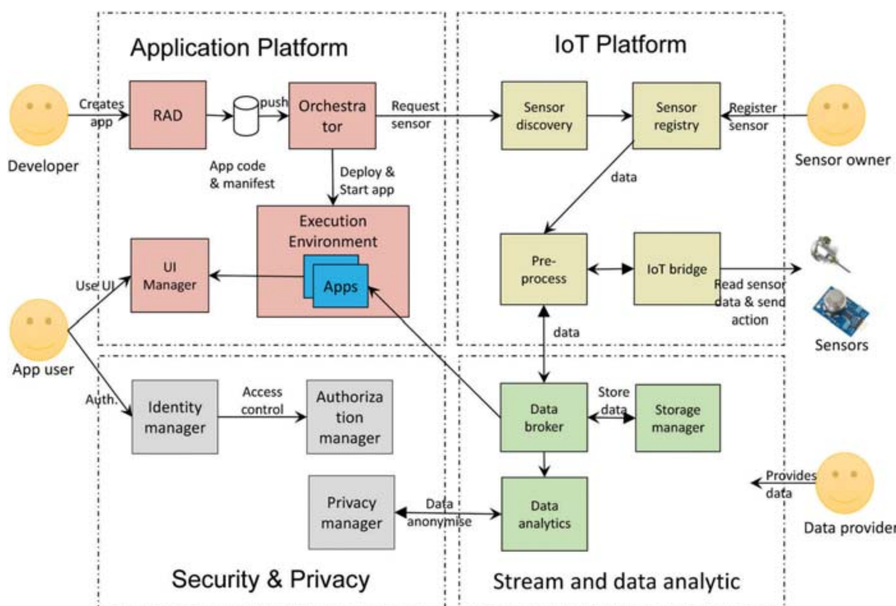

Figure 24.3 Components of the WAZIUP platform.

with the manifest. As a reminder, the manifest describes the requirements of the application in terms of:

- computation requirements (i.e. RAM, CPU, disk)
- references to data sources (i.e. sensors, internet – sources . . .)
- big data processing engines (i.e. Flink, Hadoop . . .)
- configuration of sensors (i.e. sampling rate)
- local and global application deployment

The application source code, together with the manifest, is pushed to the WAZIUP Cloud platform by the user. The orchestrator component will read the manifest and trigger the compilation of the application. It will then deploy the application in the Cloud Execution Environment. It will also instantiate the services needed by the application, as described in the manifest. The last task of the orchestrator is to request the sensor and data sources connections from the IoT components of the architecture. The sensor discovery module will be in charge of retrieving a list of sensors that matches the manifest description. On the left side of the diagram, the sensor owners can register their sensors with the platform. External data sources such as Internet APIs can also be connected directly to the data broker. The sensors selected for each application will deliver their data to the data broker, through the IoT bridge and pre-processor. This last component is in charge of managing the connection and configuration of the sensors. Furthermore, it will contain the routines for pre-processing the data, such as cleaning, extrapolating, aggregating and averaging. Historical data can be stored using the Storage manager.

The Security and Privacy domain contains three components: the Identity Manager, the Authorization Manager and the Privacy Manager. The first one is in charge of providing the identification, the roles and the connections of the users. The Authorization Manager provides the access policy for each of the WAZIUP resources. Finally the Privacy Manager provides services for the privacy of communication and also the anonymization of data.

24.7 WAZIUP Test-Beds

We will deploy a network test-bed at Gaston Berger University (UGB), Saint-Louis, Senegal, to validate the sensor and gateway platforms and to test various sensor settings in various rural environments. Computing facilities at UGB will host the WAZIUP platform to test advanced sensor and data management. The Internet access will also enable the small-size, single-application scenarios where public IoT data clouds will be used.

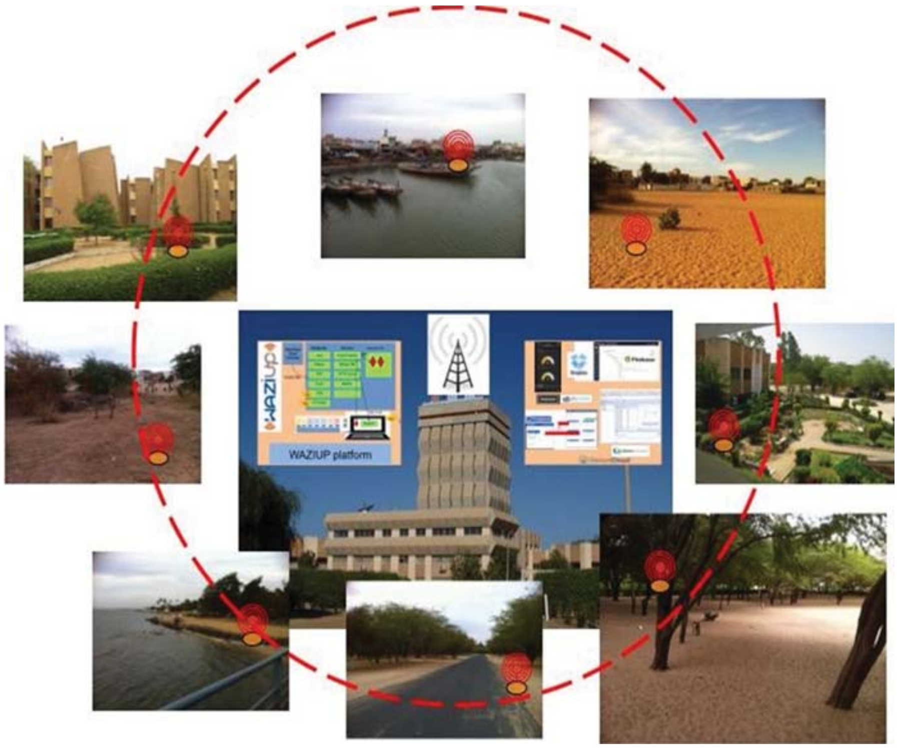

Figure 24.4 Deployment of sensor nodes around a gateway use case integration.

As can be seen in Figure 24.4, UGB has high buildings for the LPWAN antennas installation. By deploying LPWAN devices we can build a test-bed allowing LPWAN connectivity of IoT devices within a range of more than 15Kms in LOS in typical rural areas. In addition, the geographic location of UGB perfectly suit our needs as it is located within LPWAN radio range of the downtown Saint-Louis city as well as within range of many typical rural areas for test diversity, such as small villages, crop field and farms.

An important feature provided by WAZIUP is the possibility to run the sensor-gateway system in an autonomous manner, without Internet connectivity nor access to dedicated servers. The gateway can therefore also store data locally and make them available through local computing facilities (e.g. laptop, smartphones, tablets) for standalone surveillance applications. Figure 24.5 illustrates the various scenarios that WAZIUP will support: (top) gateway will Internet connectivity provided by cellular technologies, (middle) gateway will Internet connectivity provided by a WiFi (possibly ADSL-based)

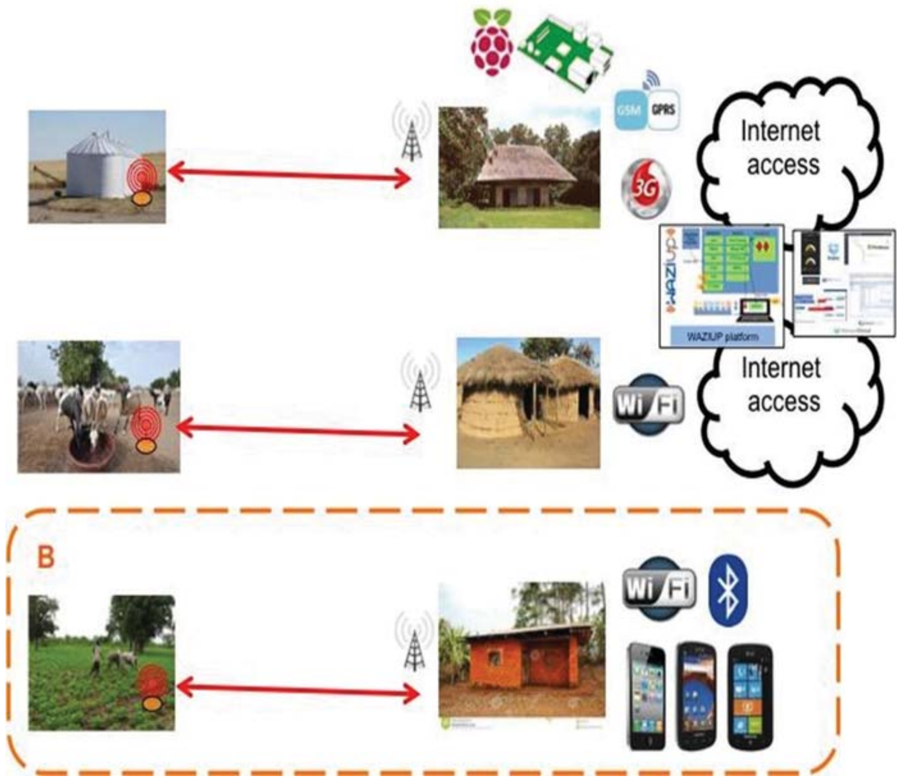

Figure 24.5 WAZIUP deployment scenarios.

access, (bottom) gateway without Internet connectivity, providing connectivity (short range) to local computing facilities (e.g. laptop, smartphones, tablets).

After the integration of the sensors and the gateway, the WAZIUP platform will be ready to receive and process information coming from the sensors.

24.8 Conclusion

With IoT, Sub-Saharan African countries can dramatically improve their productivity by enabling rapid and cost-effective deployment of advanced and real-time monitoring. However, deploying an IoT platform for Africa comes with many challenges. Among them, the most important are supporting low cost, low power, low bandwidth, and intermittent connection from Internet.

Furthermore, widely accessible technologies such as SMS and voice calls need to be supported to reach the maximum users. In this chapter, we proposed an architecture for the WAZIUP IoT Big Data platform. The concepts that underpin the WAZIUP platform are three: the PaaS approach to IoT, the data processing capacity inspired from Big Data techniques and finally the local and global Cloud. The idea of extending the PaaS approach to IoT is to propose a platform dedicated to IoT developers that can reduce the time-to-market for an application by cutting the development costs. The Big Data techniques enable the processing of the huge amount of data produced by sensors. Finally the local and global Clouds address the intermittent connection challenge: when Internet is not available, the user can still access some IoT functionalities from the local Cloud. The project will develop several applications use cases to validate its concepts. The application cases selected are precision agriculture, cattle rustling, logistic & transport, fish farming and urban waste management. Each use cases will be developed and deployed in one of our test-beds in Africa.