An Architectural Framework Proposal for IoT Driven Agriculture

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Abstract. The Internet of Things is paving the way for the transition into the fourth industrial revolution with the mad rush of connecting physical devices and systems to the internet. IoT is a promising technology to drive the agricultural industry, which is the backbone for sustainable development especially in developing countries like those in Africa that are experiencing rapid population growth, stressed natural resources, reduced agricultural productivity due to climate change, and massive food wastage. In this paper, we assessed challenges in the adoption of IoT in developing countries in agriculture. We propose a cost effective, energy efficient, secure, reliable and heterogeneous (independent of the IoT protocol) three layer architecture for IoT driven agriculture. The first layer consists of IoT devices and it is made up of IoT driven agriculture systems such as smart poultry, smart irrigation, theft detection, pest detection, crop monitoring, food preservation, and food supply chain systems. The IoT devices are connected to the gateways by low power LoRaWAN network. The gateways and local processing servers co-located with the gateways create the second layer. The cloud layer is the third layer, which exploits the open source FIWARE platform to provide a set of public and free-to-use API specifications that come along with open source reference implementations.

Keywords: IoT · FIWARE · LoRaWAN

1 Introduction

The Internet of Things (IoT), also known as the Internet of Everything, has moved from hype to reality with the continuous rush of connecting physical devices or things to the Internet. The first industrial revolution was marked

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by mechanization with the invention of the steam engine, the second industrial revolution by the discovery of electrical and other forms of energy to power factories for mass production, the third industrial revolution by the combination of advances in electronics and the digital revolution that introduced computers to automate production. Now the Internet of Things is paving the way for the fourth industrial revolution where every component of the factory is being connected to each other and to the Internet to permit real time management and control of factories which has led to the so-called Industry 4.0.

A similar evolution is taking place in the agricultural sector, from the first agricultural revolution that was labour intensive, to the second agricultural revolution marked by mechanized farming which resulted from the invention of the steam engine in the first industrial revolution and the discovery of electrical and other forms of energy in the second industrial revolution, to the third agricultural revolution motivated by advances in biotechnology, genetic engineering and the need to feed the rapidly increasing population. The recent use of IoT and other information and communication technologies to design smart farms and to automate a lot of farming processes in order to boost food production can be regarded as setting the pace for another agricultural revolution. The Industry 4.0 trend, which is powered by IoT is transforming the production capabilities of all industries, including the agricultural industry resulting in agriculture 4.0 [38].

The major challenges to the deployment of IoT solutions in farms located in rural areas, especially in developing countries, have limited Internet connectivity, insufficient (or no) energy supply, and the high cost of the infrastructure relative to the income of an average farmer. In this paper we survey agricultural challenges that could be addressed with the use of IoT and the challenges to the adoption of IoT in developing countries and then propose an architectural framework for IoT driven agriculture. This study was carried out based on the African context but can be adapted to address agricultural challenges in other developing countries.

The rest of the paper is organised into six sections. Section 2 contains a short review of related literature. Section 3 contains the assessment of agricultural challenges while in Sect. 4, key challenges to the adoption of IoT in developing countries are discuses with focus on Africa. Section 5 contains the proposed reference architecture for IoT driven agriculture and conclusions and future research work is in Sect. 6.

2 Review of Related Literature

Like other technological innovations, there are relatively negligible efforts toward IoT research and innovation in Africa as the continent has always waited for other continents such as Europe, North America, and Asia to develop technologies based on their needs and the continent end up adopting technologies that do not fit its realities and challenges [42]. Recent findings [47] revealed that the majority of the information about IoT in Africa is found in the categories of news, magazines, and other trade publications with relatively very little scientific publications on IoT in Africa. It is very important that more scientific research should be conducted to develop IoT solutions that will address some of the important challenges of the continent, the state of deployment, innovation progress, and other social and economic aspects of IoT in Africa.

The key IoT enablers, the state of IoT deployment and a proposal of possible fields including agriculture where IoT can be used to address some of the challenges in Africa were discussed in [43]. A preliminary research studies in [13] assessed the level of preparedness of the economies in Sub Saharan Africa to adopt IoT and their findings revealed that the Sub Saharan African (SSA) region is lagging behind other regions in four out of the five indices that were considered which include Network Readiness Index, ICT Development Index, Global Innovation Index, Global Competitiveness Index, and Knowledge Economic Index (KEI). Areas, where IoT can play a significant role in increasing prosperity and reducing poverty in Africa, through enhancing basic services and sectors such as agriculture and healthcare, were discussed in [47]. The potential of IoT to reduce poverty in rural communities in South Africa and Zambia were investigated in [12] with emphasis on agriculture while some few areas where smart farming can be applied to create a direct impact on farmers in SSA region were evaluated in [11].

According to the 2016 report on the demographic profile of African countries by the United Nations Economic Commission for Africa, the population of African countries has nearly trebled from 478 million in 1980 to 1.2 billion in 2015 and it is expected to reach 2.4 billion by 2050 [40]. There is a need to adopt innovative and efficient methods to meet up with the challenges introduced by the rapid population growth. Due to the slow adoption of mechanized agriculture similar to what is happening in other industries in Sub-Saharan Africa, land productivity is among the lowest in the world, with over 60% of farm power provided mostly by women, the elderly and children [41].

Fog Computing is based on the Cloud Computing paradigm and extends it to the edge of the network, adding a middle layer of communication and data processing between the end devices and the servers located in the cloud. It has been proved as an architecture well suited for IoT applications [50] and it has been shown to have good performance in terms of latency and reliability [48]. It has been proposed to describe this network of interactions [49], and is well suited for lightweight edge processing in IoT applications such as smart cities, health, agriculture etc. The fog layer is, therefore, used to shift some of the regular lightweight processing from the cloud closer to the IoT devices (IoT layer). A FIWARE based fog computing architecture for smart cities that moves stream processing tasks to the edge of the network to reduce latency was proposed in [5].

FIWARE (where FI stands for Future Internet) is an open source platform that makes it easy to build and deploy sophisticated and innovative internet applications with relatively reduced costs and complexity of serving large numbers of users (especially IoT devices) globally and handling data at a large scale. It provides a set of public and free-to-use API specifications that come along with open source reference implementations. It is made up of seven main parts called “generic enablers” and domain-specific enablers for certain domains like smart cities, energy [6], agriculture etc. The basic functioning of the FIWARE is based on the Next Generation Service Interface (NGSI) open API which defines the data model (context entities, context attributes, and context metadata), context data interface and context availability [3]. The NGSI enables openness and interoperability due to its powerful and simple RESTful API which enables access to the IoT context information [5] regardless of the IoT communication protocol used.

3 Assessment of the Agricultural Challenges in Africa

Despite its potential, the agricultural sector in Africa is facing some challenges that include but are not limited to climate fluctuation, pests control, storage problems, theft, and farm monitoring. Majority of the agricultural challenges in the continent can be addressed using cost effective, energy efficient and reliable IoT solutions in order to increase agricultural productivity.

Climate fluctuation is a global challenge, which has led to the occurrence of extreme temperatures; increasing aridity; and unpredictable rainfall. These fluctuations in environmental variables have led to an increase in malnutrition and infectious diseases in SSA as it is gradually disrupting the rainfed agricultural systems on which the majority of the population rely on [22]. Rapid and extreme fluctuations in temperature and humidity is also a threat to livestock farming such as poultry farming as poultry birds are very sensitive to temperature, humidity, and air quality. The combination of climatic and non-climatic drivers and stressors will likely exacerbate the vulnerability of Africa's agricultural systems to climate change, coupled with the fact that some African communities do not have adequate capacity to cope with or adapt to, the negative impacts of climate change [21]. The UN Secretary General, António Guterres in his speech at the climate summit 2018 in Poland said that climate change is the most important issue that we are facing, that farmers in the Sahel are losing their livelihood due to climate change. The authors in [20] revealed the negative impact of climatic fluctuations on agriculture in Nigeria and recommended that a sustained increase in agricultural productivity can be achieved by using innovative technologies to control the climate fluctuations. The IoT technology could be leveraged to automate the control of environmental variables such as temperature, humidity, lighting, soil moisture etc in order to optimize the resources used and also to improve agricultural productivity.

According to findings from the Climate Change, Agriculture and Food Security (CCAFS) research program, one-sixth of global food production is lost to pest and that climate change may bring a greater risk of pests and diseases to African agricultural systems, affecting crop, livestock, and fisheries productivity [19]. The tropical climate in Africa creates a good breeding ground for pests such as insects, birds, giant rats, and other animals that damage crops and prey on organisms needed in the farming ecosystem. Pests, such as e.g. wheat weevil, can cause great damage to the harvested grains. The challenges in pest management are detecting the presence of pests, predicting a possible outbreak of pests and diseases, and to have good response strategies to keep pests damage under control. IoT could be used to detect the presence of pests, predict the possible outbreak of pests and advice farmers on possible techniques to keep its effects under control.

Theft of farm products, tools, and other assets is a serious threat to the agricultural systems in developing countries. This is as a result of the rising level of unemployment and poverty, especially in poorly developed rural communities. Livestock farming is seriously affected by theft wherein one successful theft operation, the time, energy and investments of the farmer can be rendered useless. It is even more complicated in areas where the farms are located far away from the human settlement as intruders can easily get away unnoticed. Therefore, it is important to develop anti-theft systems that will be able to detect intruders, scare them away and inform the farm owner in real time and possibly ensure timely intervention of local security agents or neighbors. With the use of IoT, it is possible to develop reliable and affordable anti-theft systems based on the context of the given environment in order to reduce the chances of farmers losing their investments on a single theft operation.

The inability to monitor the crops or livestock in real time in order to schedule farming activities and reduce the number of visits to the farms makes farming relatively expensive and time demanding to small scale farmers, who may have other jobs to sustain their families. Most of the crops cultivated in the tropics require careful monitoring to determine when to remove weed that may overshadow crops, when to apply fertilizer and when to harvest. Weeds are uncultivated plants that are competing with cultivated plants [18], they can have negative effects on the crops if not removed on time, such as reduced crop yield; compete with cultivated crops for soil water thus increasing irrigation demands during the dry season, reduce chances of cross-pollination, and damage plant health. It is also challenging to know exactly when the crops are ready for harvesting as some crops may get ready unexpectedly and may be damaged before the estimated time. Livestock farmers face similar problems of time-consuming and labor intensive activities such as giving food and water to the animals, monitoring the well being of the animals and cleaning the environment where the animals are kept. IoT can be used to automate some farming activities which will reduce the number of visits to the farm and therefore, save the time and cost of running the farms.

Farmer and traders dealing with agricultural products in Africa face a serious challenge of storing products like fruits, vegetables, tubers, and cereals. As the agricultural systems in Africa are rainfed, the majority of the crops such as cereals and tubers cultivated during the rainy season must be preserved and marketed throughout the year even during the non-harvesting season. Monitoring the state and quality of farm products along the food supply chain challenge that needs to be tackled by all the stakeholders in the agricultural supply chain to ensure that appropriate actions can be taken to avoid food wastage. IoT sensors can be used to monitor environmental conditions such as temperature and humidity under which the farm products are stored, to detect any abnormalities and alert the owner to take appropriate actions.

4 Key Challenges to the Adoption of IoT Driven Agriculture

There are a lot of research and innovation projects going on in Europe, America and Asia to develop, standardize and deploy IoT technologies but very little is being done in the African continent just as in the past technological revolutions [42,44]. Due to very little research and innovation in Africa, most of the technologies and use cases developed outside of the African continent, some times do not fully address the challenges of the continent and their capabilities not fully exploited. The adoption of IoT can trigger innovation in other sectors such as agriculture, health, transportation and heavy industries, which gives the hope that the continent can leapfrog technologically to catchup with the rest of the world.

Insufficient power supply is one of the challenges to the adoption of IoT in Africa and SSA in particular that constitute 46 of Africa's 54 countries. According to a series of reports from Oxfam and the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley, the region has the lowest energy supply capacity with the most acute forms of energy poverty in the world. Poor management of energy utility services and the high cost of energy [17], makes it difficult to automate some farming processes which require energy to power machines, sensors, communications devices, and local data processing. However, African nations are progressively upgrading their energy capacity and also embarrassing renewable energy initiatives which indicate a promising future for IoT in Africa. Due to limited supply of energy and high cost of energy we advocate the development of secure, reliable and energy efficient IoT systems in order to reduce the cost of managing IoT system and increase the rate of adoption.

Limited internet connectivity and the high cost of internet connection in some African countries is a hindrance to the adoption of IoT in the African continent. Despite the steady growth in mobile (2G, 3G and 4G) and internet connectivity, Africa is still far behind the rest of the world, with a penetration rate of 35.2% representing 10.9% of the total world internet users [16]. Due to insufficient experts, little competition among operators, poor regulation of ICT and telecommunication sectors in most African countries, mobile coverage is low, the quality of internet connectivity is poor and cost of internet connectivity is relatively high compared with other continents [15]. Poor and high cost of internet connectivity will make IoT solutions relatively difficult to manage and unaffordable for low income earners especially farmers in rural communities. Despite the significant effort by must nations to develop modern telecommunication infrastructure, there is still need to develop IoT solutions to addresses the needs of the continent while optimising the cost of energy, connectivity and provisioning but ensuring an acceptable level of security and quality of service.

Insufficient skilled labour in the area of IoT, data science, and agriculture which could be as a result of mass movements of graduates from STEM (Science, Technology, Engineering and Mathematics) fields for greener pastures. Majority of farmers in African rural communities are small scale farmers and a lot of them little or no formal or informal training on agricultural practices that can improve yields. The problem of insufficient IoT skills is because many universities have not yet adopted IoT as a formal course or program. In order to tackle the problem of insufficient IoT skills, we are currently developing free IoT courses with remote laboratory infrastructure under the IOT-OPEN.EU (Innovative Open Education on IoT: improving higher education for European digital global competitiveness), ERASMUS+ Key Action 2 (Strategic Partnership) project. This will provide students and IoT enthusiast including those from developing countries free access to our resources for learning and research. We are building other cooperation with institutions in Africa as part of IoT Technology for Sub Saharan Africa (ITSA) project.

The rate of technology adoption in Africa is very low especially in the central African Sub-region which have the lowest technological adoption, with mechanized agriculture and IoT still being a hype. Technological adoption requires an updated educational curriculum but most developing nations do not have dynamic educational curriculum to keep them abreast with the new developments in hardware, software, and communications technologies [14]. It is also difficult to convince small and medium-size enterprises to buy technological solutions as they are sometimes reluctant to pay for technological solutions partly, due to inadequate financial capital. Adequate attention is not given to the agriculture and IT sectors by some developing countries as their main focus is on natural resources like oil, minerals, natural gas etc which are already being stressed. IoT (and IoT-driven agriculture) research and innovation initiatives based on local problems especially the energy, connectivity, security and cost constraints will enable an increase in the rate of technology adoption.

Another challenge to the adoption of IoT generally is the fact that IoT has a lot of cyber security challenges, as it has been predicted that by 2020, 25% of cyber attacks will be targeted towards IoT devices [9]. The 2016 high-profile Mirai attack conducted with the use of an army of IoT botnets was catastrophic as it disrupted internet services for more than 900,000 Deutsche Telekom customers in Germany, infected almost 2,400 TalkTalk routers in the UK [8] and disrupted the DNS services of Dyn, which further led to the disruption of services of website such as Twitter, Amazon, Reddit, and Spotify [9]. According to a research survey in [10] it was found that they are very few cybersecurity initiatives in the African continent as the few countries that had cybersecurity initiatives ended only at cybercrime legislation with little or no actions. The fact that IoT systems are highly vulnerable and can be easily exploited might scare a lot of African enterprises from adopting IoT as it may be considered as a potential threat to their systems.

5 The Proposed Architectural Framework

In most IoT solutions, the sensing devices are usually powered by batteries and some low power communications protocols have been developed to minimize energy consumption. Currently, security in IoT networks is the major preoccupation as IoT devices can easily be compromised due to their low processing power capabilities resulting from its power constraints. However, power and security are not the only constraints when deploying IoT solutions especially in developing countries but also internet connectivity and the cost of setting up and managing the IoT infrastructure. Our proposed architectural framework for IoT driven agriculture takes into consideration energy, internet connectivity, security and cost constraints. Our framework is made up of three layers which are: the sensor layer, the fog layer and the cloud layer.

5.1 The IoT Layer

The IoT layer is made up of IoT driven agriculture systems which include sensors that measure environmental variables such as temperature, humidity, soil moisture, air quality, gas concentration, vibrations and sound, cameras for crop/livestock and security monitoring, and agricultural systems to be controlled such as irrigation machines, heating systems, fans, lighting systems, and alarm systems. Some of the IoT driven agriculture use case applications that were considered include but are not limited to those shown in Fig. 1 which include: smart poultry systems, smart irrigation systems, theft detection systems in farms, pest detection systems, crop monitoring, food storage monitoring, and food supply chain. Details of cost-effective use case applications for IoT-driven agriculture based on the context of developing countries have not been presented due to limited space but will be provided in subsequent works.

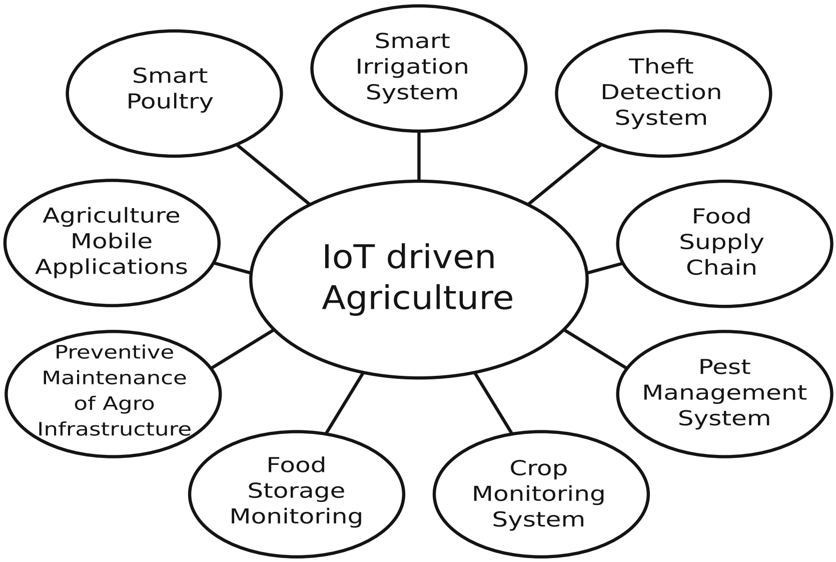

Fig. 1. Proposed IoT driven agriculture use cases for sustainable developement

Due to the limited storage and processing power of the devices in the IoT layer, the data measured by the IoT sensors is usually sent to a cloud platform for advanced processing and the feedback from the cloud platform is used to control some systems, which are systems in the farming process in this case. This has resulted in the need of low power transmission technologies and protocols for IoT such as ZigBee, 6LowPAN, BLE, NB-IoT LoRa, LoRaWAN, Sigfox, Weightless P. IoT driven agriculture use case applications require mostly LPWAN (Low Power Wide Area Network) communication technologies where sensors from many farms can be connected to one gateway. Some of the most popular LPWAN technologies include Sigfox, Weightless P, NB-IoT LoRa, and LoRaWAN.

In order to ensure low power communication between the IoT sensor devices deployed in open fields or in poultries and the gateway, the LoRa communication standard is proposed. The LoRa communication uses a proprietary spread spectrum modulation based on the Chirp Spread Spectrum modulation (CSS) and which allows achieving very good sensitivity and uses fixed channel bandwidth. The LoRa devices are very energy efficient and may operate up to a few years on a single battery. The LoRa Alliance (https://lora-alliance.org) has developed an LPWAN protocol for deployments where end-devices have limited energy and need to transmit a small amount of data (e.g. tens of bytes) at a time. The LoRa WAN provides two-way communication, with three different classes of devices (A, B and C) with different schemes of traffic transmission initiation. In addition to its energy benefits, LoRa communication standard is well suited for the application of IoT in agriculture because it provides a large radio network courage up to several kilometers.

One of the major challenges in the adoption of the LoRa communication standard for IoT driven agriculture is the transmission of multimedia data such as voice and images. Monitoring of crops to determine harvest times, the presence of pests or weed, monitoring of stored food, monitoring of livestock, and security monitoring for theft detection require the transmission of multimedia data. The LoRa technology was designed to transfer short telemetric data but experimental results of multimedia data transfer using LoRa technology with a better image compression using JPEG 2000 and voice compression using the A-law were obtained in [1]. Since data updates in IoT driven agriculture may be necessary only at certain times of the day, the bandwidth may be used to transmit multimedia data but the problem is the time and the energy needed to transmit multimedia data and the quality of the images and sounds. We also recommend that other methods may be used for delivery of high-quality multimedia data such as WiFi and the use of drones though these methods may be costly to small scale farmers especially in developing countries. Thus we will perform a study on the power requirements and optimization for multimedia data transmission using LoRa based on measurements.

5.2 The Fog Layer

In must IoT deployments, cloud platforms are used for processing of IoT data but it requires good internet connectivity. The cloud approach also have some drawbacks like high latency in IoT applications where the systems at the IoT layer requires real time control as the case of some IoT driven agriculture systems and the issue of security as the data may be compromised in the course of transmission within the internet backbone to a distant cloud server for example, attacks such as traffic reordering in the case of temperature, humidity, soil moisture etc. measurements and also traffic dropping attacks may disrupt the control process. The fog computing paradigm is a better approach to mitigate some of the drawbacks of using only the cloud for data processing by shifting some of the lightweight processing to the edge of the network which is closer to the IoT layer. To merge LoRa with Fog Computing paradigm we propose an architecture for IoT driven agriculture shown in Fig. 2. The LoRa WAN access point can be installed to provide wireless communication between the IoT layer and the fog layer alongside a local computer (e.g. a Raspberry Pi or a cheap PC). The fog/edge computing architecture is suited in this context because even if the internet is temporally unavailable for any reason the local network and the fog nodes will still keep the services working and local processing also offers energy benefits in terms of the number of communications.

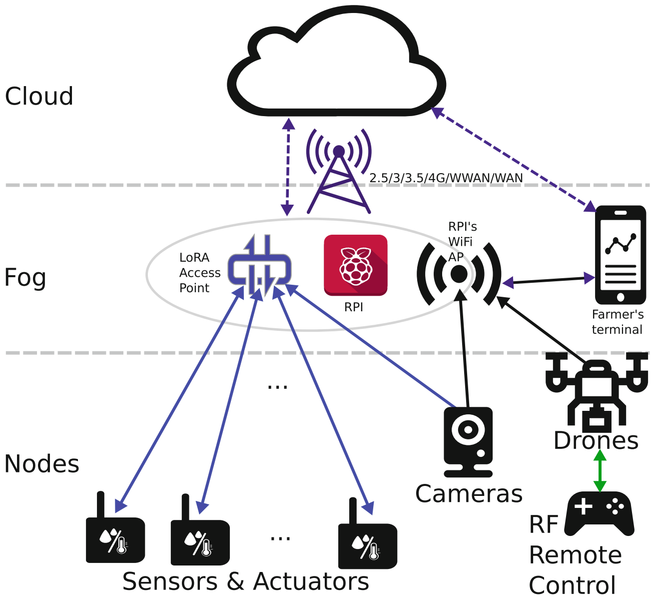

Fig. 2. Proposed architecture for IoT driven Agriculture

The fog layer in the proposed reference architecture for IoT driven agriculture shown in Fig. 3, is made up of the IoT agent, a lightweight context broker, a complex event processor (CEP), a LoRaWAN gateway and a WiFi access point. The basic functioning of FIWARE is based on the NGSI OPen API which defines the context data model, the context data interfaces and context availability but the NGSI specifications are not supported by the devices at the IoT layer.

The IoT agent between the FIWARE fog computing system and the sensors and agricultural systems at the IoT layer translates the different communication protocols such as CoAP transport, HTTP ultralight, MQTT transport, and OMA Lightweight M2M into NGSI specifications and hence the FIWARE provide open specifications for IoT deployments as it is independent of the protocols running on the different IoT devices from different vendors. IoT agents have been implemented to enable the exchange of commands between the devices at the IoT layer and the FIWARE context broker, including one that provides an interface between the LoRaWAN servers and the FIWARE context broker.

The lightweight context broker keeps track of the context entities such as: soil moisture, temperature, humidity, gas concentration, water level, light intensity etc registered by the different context data producers (sensors, actuators, drones etc.) and also keeps track of the different publish/subscribe request for the different context entities. When a new context update arrives the current value of the context attribute (moisture value, temperature value, humidity value etc.) is updated and therefore, the current context data must be forwarded to the database, the CEP and the cloud context broker for advanced processing. The CEP should be able to filter, aggregate and merge data and process the context data so that when any of the event processing rules or conditions configured is meet, the CEP generates an alert and publish to the lightweight context broker. For example, if the temperature or the soil moisture level is below or above the required level, the CEP can generate an alert and publish on the lightweight context broker which can then send notifications to the consumers who have subscribed for this context event (farmers, actuators, cloud context broker etc).

5.3 The Cloud Layer

The introduction of fog or edge computing does not eliminate cloud computing in IoT systems as there is always a need for advanced and computationally intensive processing. Computationally intensive processing such as big data analytics, advanced data visualisation, GIS (Geographic Information System) processing to generate thematic maps and statistics, AI-based knowledge discovery, data driven agriculture applications etc should be shifted to the FIWARE cloud. Details of the FIWARE cloud are not provided by our reference architecture but more details can be found in [6]. The FIWARE cloud platform contains a context broker whose data producers and consumers are the cloud CEP, the lightweight context brokers at the fog layer, advanced data analytics applications, third-party IoT driven agriculture applications and users. In order to ensure that the current context data is not overwritten by new ones, the context data is written to a database. Since the cloud and the fog layers both support the NGSI specifications, there is no need for an agent for protocol translation.

In real and large scale deployment of this kind of architecture, the cloud servers may be located far away from the fog nodes and the traffic needs to be transported over traditional internet infrastructure. As mentioned above, the IoT traffic may be attacked during the course of transportation or may experience longer delays that may affect real-time control applications in IoT driven

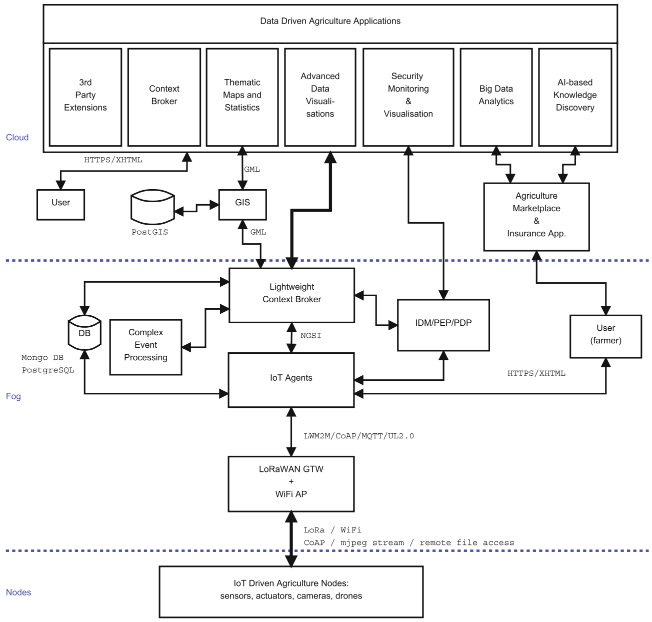

Fig. 3. Proposed reference architecture for IoT driven agriculuture based on fog computing/edge computing and fiware

agriculture. Networks operators could adopt an architecture proposed in the SerIoT (Safe and Secure Internet of Thing) project [2] for secure transportation of IoT traffic from the fog nodes to the cloud servers. The SerIoT network is a self-aware Software Defined Network (SDN) that consist of forwarding elements and a smart SDN controller that is based on Cognitive Packet Network (CPN) and its Random Neural Network (RNN) with reinforcement learning. The smart controller computes and updates the flow rules based on a goal function whose metrics are Security and Safety, Quality of Service and Energy usage. The fog nodes could be connected to a single edge SerIoT node which can then source-route the traffic through intermediate nodes towards the cloud servers. The SerIoT holistic solution for secure Internet of Things also contains security monitoring, intrusion detection, honeypots etc.

FIWARE provides a security generic enabler (GE) to ensure the security of the FIWARE platform as security is one of the must compelling requirement of IoT deployments. The FIWARE security GE components were discussed in [6]. The Identity Manager (IDM) can create users (devices in the IoT layer, other applications, and operators), roles and permission. The Policy Enforcement Point (PEP) which is a proxy server performs authentication and optional authorization checks. The Policy Decision Point (PDP) provides authorization services by deciding the actions the users are allowed to perform. It is possible to implement advanced security analysis, visualization and reporting in the cloud platform.

6 Conclusions and Future Research Works

We have proposed a three-layer reference architectural framework for IoT driven agriculture that takes into consideration energy, internet connectivity, security and cost constraints. It consists of the IoT layer which is made up of low power LoRaWAN networks of IoT driven agriculture systems, and then a FIWARE based fog and cloud computing layers. Due to the page limit, a lot of details about the IoT driven agriculture systems in the IoT layer have been left out but will be provided in future works. We intend to perform a study on the power requirements and optimization for multimedia data transmission using LoRa communication standard based on measurements and simulation because a lot of IoT driven agriculture application requires audio and image transmissions. We will equally develop analytical models for packet aggregation mechanism at the fog node before there are transported through the internet backbone to the cloud servers. This is to reduce the processing overheads of short IoT packets and to optimize energy consumption at the backbone because it is expected that billions of IoT devices connected to the fog nodes will be generating huge amounts of short IoT packets. We also We will also test this architecture with some selected use cases.

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