Smart Farming in Emerging Economies

Stephen Simei Kimogol

Thesis submitted for the degree of
Master in Informatics: Programming and System Architecture
(Distributed Systems and Networks)
60 credits

Institute of Informatics
Faculty of mathematics and natural sciences

UNIVERSITY OF OSLO

Spring 2019

Clear goal definition
- Research questions:

- Evaluation criteria:

- Evalution

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http://www.duo.uio.no/

Printed: Reprosentralen, University of Oslo

Summary

summary

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2 Background

The continuous growth of the world population and climate change poses a great threat to food security. Population growth will have an effect on the capacity of the environment on food production due to changes and availability of arable land and increased fluctuations of weather patterns have an impact on food production. In spite of this, food production globally has to increase by 70 % by 2050 in order to feed the growing population [1]. These demographic, climatic and environmental changes encourage the use of innovative technologies to address food security problems. There is a need to use technology to regulate the consumption of depleting resources, increase productivity and enhance resilience.

2.1 Agriculture and Technology in developing countries-Setting the Scene

2.1.1 Population, climate change and agriculture

Besides providing food, agriculture is a source of livelihood for 36 % of the world's task force with 40-50 % of Asia and the Pacific population and two-thirds of people in sub-Saharan Africa relying on it to make a living [6]. The effects of climate change affects food production and it is felt mostly by the people in the developing world since agriculture is the main source of livelihood. Farmers in these areas are resource limited and vulnerable to the effects of the climate change. Since most people depend on agriculture, which is sensitive to rainfall variability and temperature change, hunger is a significant threat in the face of climate change.

The United Nations (UN) projected in 2017 that world population will reach 9.8 billion in 2050 and over half of this population growth (1.3 billion) and 750 million will occur in Africa and Asia respectively [2]. Yet, according to the UN Food and Agriculture Organization (FAO), 821 million (one person out of every nine in the world) are currently undernourished [3] and it is estimated that the food production in Africa has to increase by 260 % by 2050 to provide food for the expected population [4]. The demand to increase in food production to feed the growing population will have effect on the ecological footprint and the current agricultural production have already created a large ecological footprint [5]. To address food security problem and at the same time reducing ecological footprint associated with food production, agriculture has to be transformed.

Figure 1: Food demand vs ecological foot print (Source: [5]) .

Climate change will only exacerbate water scarcity and unpredictability of water supply due to changes in weather patterns. Currently, 70 % of freshwater in the world is used for agriculture and there will be growing competition for water between agriculture, industries, and consumption in the cities [6]. In addition, 40 % of the rural population live in river basin areas that are classified as water scarce [7]. Water scarcity in the face of climate change will affect most the rural communities in sub-Saharan Africa and South Asia where water problem is already a challenge and have low capacities to adopt changes in climate.

2.1.2 Uptake of agricultural technologies

In these section we will discuss the uptake of agricultural technologies in developing countries, causes of low uptake and opportunities technological developments offer.

Agricultural engineering and mechanization contributed to rise of large-scale farming and increased production and transformation of countries from agriculture to industry-based economies [8]. With the use of modern agricultural approaches like irrigation and fertilizers, the cereal production in East Asia increased by 2.8 % a year between 1961 and 2004 while there was stagnation of yields in sub-saharan African countries that didn't adopt those approaches[9].

The importance of technology couldn't be stressed more. Nonetheless, the uptake of advanced agricultural technologies has been restricted to the developing countries. They are many factors leading to this.

2.1.2.1 Socio-economic Factors The social-demographic and social-economic factors affect the adoption of new technologies [10, 11]. Farmer's education level, age and computer confidence are among the factors that hinder farmers choice of technology. The knowledge to existence of technology is also important factor in the adoption of technology [12] and in many cases even the existing knowledge and technologies have not reached farmers in developing countries [13]. .

2.1.2.2 Infrastructure Adaption of smart farming in developing economies is mostly hindered by insufficient or lack of infrastructure. Access to communication infrastructure and the Internet are key enablers in the adaption of technology in agriculture. Information and communication technologies keep farms informed about the recent technologies in agriculture, weather conditions, financial services and enable connection with buyers [14]. However, according to International Telecommunication Union (ITU), 53 % of the world's population are still unconnected to the Internet and they could not benefit from the aforementioned benefits [15]. The UN has acknowledged the indispensability of access to information and the critical role played by communication technology. In the recently launched Sustainable development goals, one of the targets of the goal 9 seeks to 'increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020 [16]. Several mobile service are already offered to farmers, but uptake and use of more advanced devices and services e.g cloud-based services are influenced by battery life of devices and access to fast internet [17].

2.1.2.3 Cost and ownership of technology Further, there is a disparity in the research, development and ownership of new technologies since public and private investment in such technologies is concentrated in high- income countries thus limiting access to emerging countries [14]. The Eropean Union has allocated euro 95 billion to the European Rural Development Fund for modernisation of agricultural industry between 2007 and 2013 [18].

2.2 Digital Dimension of Agriculture

The use of advanced technologies has been integrated to farming and new concepts like precision farming/agriculture and smart farming concepts have emerged. While these concept all revolve around modernization and use technology in agriculture, they have some difference.

2.2.1 Precision Farming

According to a report by European Parliament on Precision agriculture and the future of farming in Europe, precision agriculture is defined as: "a modern farming management concept using digital techniques to monitor and optimise agricultural production processes" [19]. The focus is optimization of farm inputs. It ranges from application the correct amount of fertilizers to the specific part of the field based on soil properties, precise water use and to giving the correct amount feed to specific animal. Sensor, satellite navigation and positioning technology are an indispensable part of Precision Agriculture. Precision farming commenced when GPS signals were made available for the general public [20]. Precision farming has successfully been implemented in large-scale farms in Central and Northern Europe, the USA and Australia with use of Controlled Traffic Farming (CTF) and auto-guiding systems showing clear benefits [21]

According to [22], the development of precision agriculture is as a result of growth of farm enterprises and move from scaling of farm assets to optimization of assets. With the increase of cost of the farm inputs and regulations e.g. use of fertilizers and unpredictability due to climate and market prices, different systems that collect and manage data were developed to aide farmers in making right decisions. Precise monitoring and control are done to manage spatial and temporal variability of crops, animals and soil factors[5].

2.2.2 Smart Farming

Smart Farming is a recent phenomenon that came into being with inclusion of computing technologies and transmission data in agriculture [23]. It overlaps with technologies like precision farming and management information systems that have been derived from farm management information systems (FMIS) [23]. It is an extension of precision agriculture where management is based not only on the location but also on data that is triggered by real-time events [5]. Figure 2 shows different technologies that are used smart farming.

Figure 2: A smart farming technologies (Source: [18]).

In Smart Farming, the emphasizes is on the use of information and communication technology in the cyber-physical farm management cycle [24]. The advancement of nanotechnology in the last decade enable production of small and inexpensive sensors [25]. Moreover, cloud computing and internet of things will enhance the development of smart farming [5].

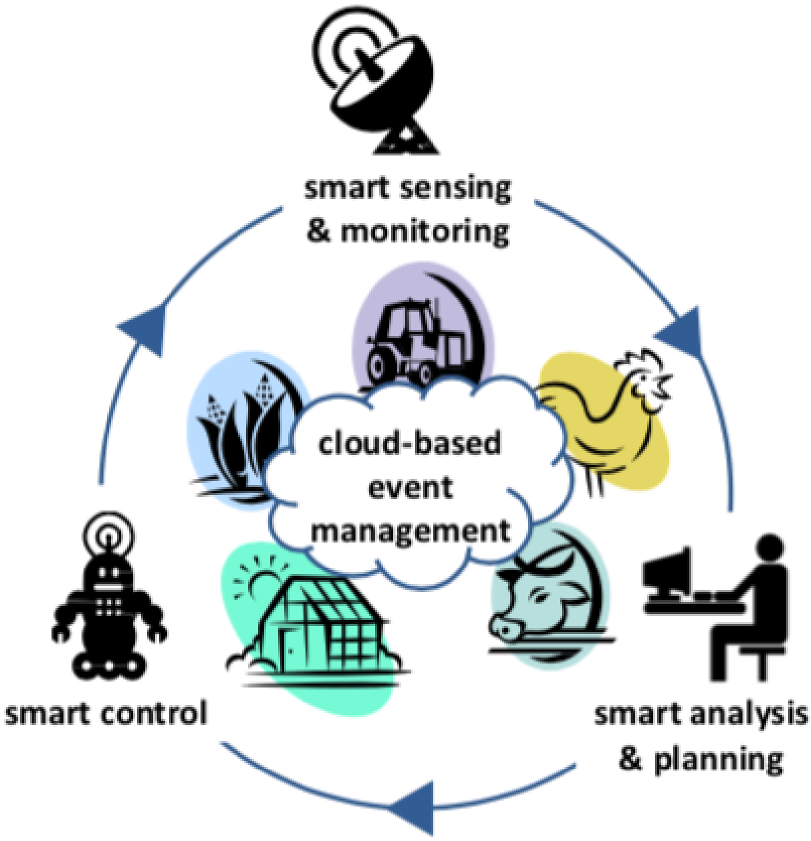

Figure 3: An ideal cycle of smart farming (Source: [22]).

Figure 3 shows a smart farming as cycle of sensing, monitoring, analyses and cloud based control of farm events. The harvesting of data from sensors deployed in the fields aid decision making process or animal health, remote monitoring and accurate diagnosis of the soil and crop conditions and timely interventions. Farmers will also have access to historical data of weather and other inputs and they can make informed decisions. This will result in less waste, efficient use of resources and effective food profuction thus reduction of the ecological footprint [26] .

how does it relate to the research question
what is my evaluation

2.3 Hydroponic farming

Growing of plants without soil has been practiced for a long time. This method of food production has been practiced earlier e.g hanging gardens of Babylon, the floating gardens of the Aztecs of Mexico. The term Hydroponics, however, is recent and was first used by W.F. Gericke of the University of California in early 1930s [27]. Hydroponics can be defined "as the science of growing plants without the use of soil, but by the use of an inert medium, such as gravel, sand, peat, vermiculite, pumice, perlite, coco coir, sawdust, rice hulls, or other substrates, to which is added a nutrient solution containing all the essential elements needed by a plant for its normal growth and development " [27].

Hydroponics farming is classified as either open (nutrient solution is not reused) or closed (where solution is recovered, replenished and recycled)[28]. Hydroponics has several advantages over the traditional farming: it can be used in areas with where in-ground farming is not possible e.g due to climate (cold and desert), areas with water scarcity and conditions where complete control of nutrient content is required and there is a need for increased productivity/crop yields [29]. Hydroponics, if adopted can address challenges faced by small holders farmers in developing countries like scarcity of water, limited arable land, labour cost and reduced long growth periods [30]. In optimal growing conditions hydroponic greenhouse far out-yield varieties produced on the field e.g Tomatoes production increased in yields by 4- 10 times [27] and for production of fodder 50 sq. m. area could produce 600 kg maize fodder in seven days compared to 1 ha of land needed to produce same amount of fodder [30]. The major limitation of adoption of in hydroponics is the initial capital required [29] especially for the small holder farmers in developing countries. However, the cost can be reduced by low cost devices/construction material [30].

Hydroponic farming is relatively new practice in most of the countries in developing countries with smallholder farmers barely having knowledge about it. Most smallholder farmers practice mix farming: farmers grow crops and keep animals. Hydroponic farming is, as such, an approach that can be used to produce food crops and fodder for farm animals. Closed hydroponic could address problems faced currently due to scarcity of water and rainfall variability. The recycling of water could affect production and necessary measurements and monitoring need to be done in order fo the farm to be economically viable. IoT could solve this problem. Sensors can collect data of the ingredients of the solutions and this can help farmer make informed decisions at the right time. Disease outbreak or chemical imbalance can easily be noticed and necessary action taken at the right time.

2.4 Requirements from Smart Farming

BREAK

2.4 Edge Computing

Edge computing has been emerging approach in distributed computing in the last few years. It extends traditional cloud computing to the edge of the network. It is worth noting that fog computing and edge computing are used interchangeably in literature. However, they are some that make distinction between these two paradigms. OpenFog consortium defines fog computing as a " as a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking anywhere along the continuum from the cloud to things. Fog computing is different from edge computing and provides tools for distributing, orchestrating, managing, and securing resources and services across networks and between devices that reside at the edge. Edge architecture places servers, applications, and small clouds at the edge. Fog jointly works with the cloud, while edge is defined by the exclusion of cloud." [31]. In [32] an in-depth comparison of edge and fog computing and other related paradigms have been made. From this, edge viewed as one the immediate first hop from IoT devices like WiFi access points or gateways.

Cloud computing has enabled users to obtain computing and storage resources provided by data centres at anytime and from anywhere [33]. Cisco Internet Business Solutions Group predicted that there would be 50 billion devices connected to the Internet by 2020 [34]. The data produced by these devices at the edge of the network pose a challenge to networks and central cloud computing. The increase in number of devices and rapid advancement of Internet technologies comes with its own unique set of challenges such as latency issues for time critical applications, storage of sensitive data at external service providers raises privacy issues and limited bandwidth to transmit large amounts of data produced by the devices [35].

Edge computing model has the potential to address these challenges. Edge computing architecture is built on edge servers that offer storage, computing and networking services and enable communication and cooperation between decentralized devices without supervision by a third party [36]. This new paradigm extends the cloud services and provides high quality, low latency services to the end users. Traditionally IoT applications have stringent requirement of low latency, but this is not the case in smart and precision farming as network performance requirements are less stringent [37]. Furthermore, in most areas in developed countries where small-scale farmers reside is associated with insufficient infrastructure and limited bandwidth. The benefit edge computing offers in this context is filtering, pre-processing, analysing and aggregation of raw data before forwarding to cloud thus reducing bandwidth used and local caching for retrieval robustness and reducing need for communication with cloud [38]. This also saves the user bandwidth if they depend on carriers data plan and also it gives the possibility of users to evaluate which connection and speed they can use at the edge [35].

2.5 Internet of Things

The term 'Internet of Things' was coined in 1999 by Kevin Ashton and is generally viewed as interconnected devices, objects, people and software. Internet of Things is rapidly developing and it continues to receive much attention due many possible market and applications scenario it offers. CISCO estimates that there will be 50 billion devices connected by 2020 [34] and McKinsey Global Institute estimated in 2015 that IoT will have economic impact of between $3.9 trillion to $11.1 trillion per year in 2025 [39]. Internet of Things is a combination of technological push and human pull for connectivity between the immediate and wider environment and it emerged from development in identification technologies e.g. RFID and bar codes and from development of networked sensors and actuators [40].

There is no agreed on definition for the Internet of things. According to European Research Cluster on the Internet of Things –IERC, Internet of Things is

“A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associate with users and their environments” [41].

A user centric definition is given by [40]. IoT is “Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless large scale sensing, data analytics and information representation using cutting edge ubiquitous sensing and cloud computing"

IoT has many applications areas and [42] has given a comprehensive taxonomy of different applications including health-care, environmental, smart city, commercial, industrial and general aspects. Smart farming/agriculture is a subsection of environmental application scenario. IoT platforms is used different agricultural sectors and the following are some of the examples: a henhouse to monitor and control environmental factors (temperature, humidity, carbon dioxide, ammonia levels [43], hydroponic greenhouse [37], monitoring and control of irrigation system in rural communities [44], smart irrigation in tunnel farming [45], smart animal farm [46].

IoT in agriculture consists of several layers interconnected things and interfaces. [25] provides a six layer framework for a full fledged agricultural solutions based on IoT. Figure 4 shows these six layers and interconnection between them. However, the service layer in this framework only doesn't edge plane and data is directly sent to the cloud and no analysis of data is done either at this stage.

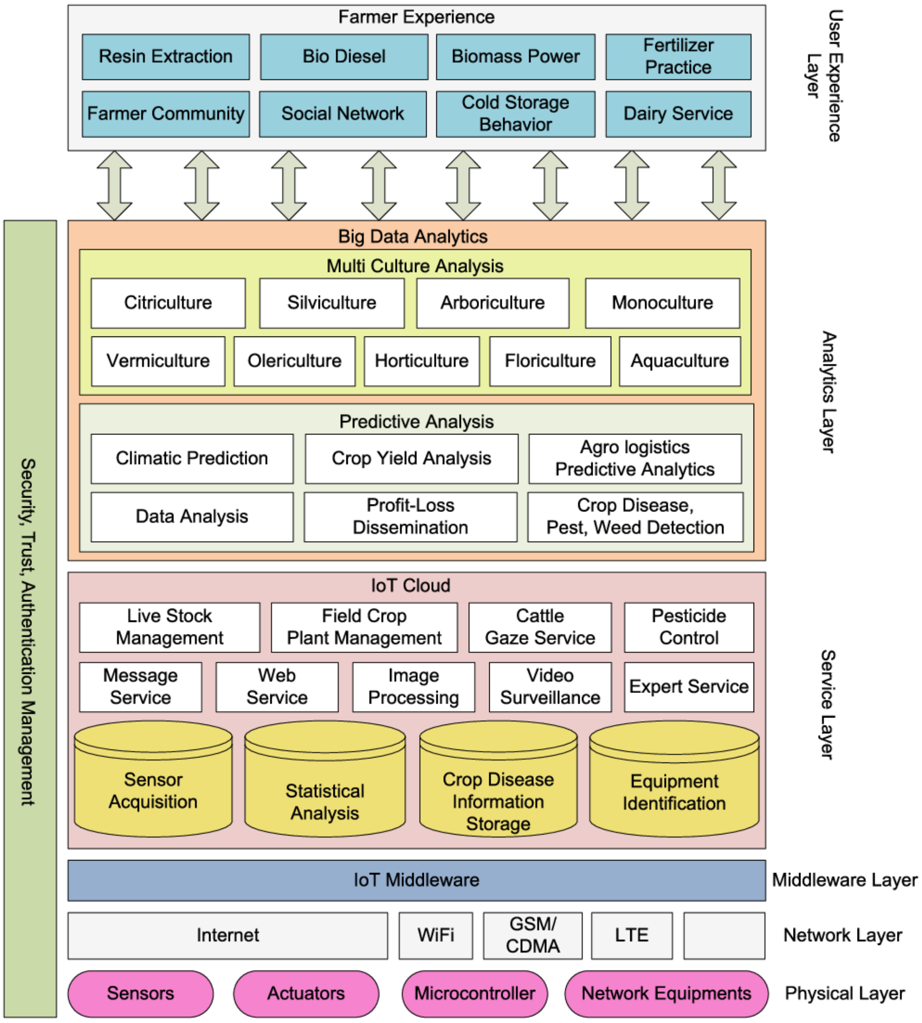

Figure 4: IoT based agricultural framework (Source: [25]).

2.6 Wireless Communication Standards

Edge vs Cloud Computing

Conclusion (related to Research Questions)

3 Related Work and State of the art

4 Implementation

5 Evaluation and future work

6 Conclusion

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