INTERNET OF THINGS

by

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**Abstract**

The Internet of Things (IoT) has created several opportunities and challenges for farmers when monitoring crops and livestock. This business report aims at assessing the impact of the existing components of a full solution chain to an organization. The report has incorporated how different low-cost sensors that can monitor crops, soil and livestock, and transmit the data to the controller. The proposed solution entails sensors, drones, raspberry Pi-ES, a base station, gateway based nodes, a Google cloud server and end user devices for the farmer. The report discusses the implementation cost of the proposed solution and the challenges likely to affect the company. Some of the security issues that the company is likely to experience are cyber-attacks which can contribute to big data loss, and lack of skilled workforce to operate the ever-changing IoT systems. The privacy and ethical considerations for the company is to implement an authentication system that identifies all the devices or users before testing the communication protocol of the IoT platform.

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**Detailed Presentation of the full Solution Chain (400 words)**

Figure 1: IoT solution for smart farm

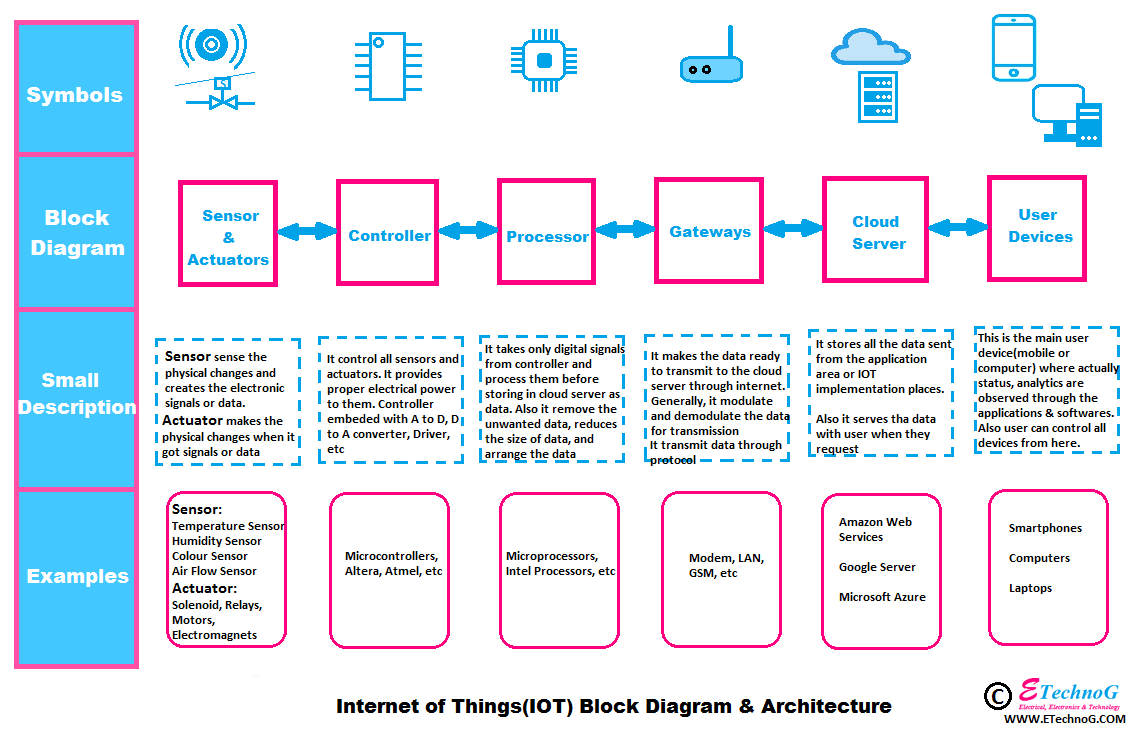


Figure 1 represents the IoT solutions for effective implementation of smart farming. The Internet of Things (IoT) refers to the interconnection of physical devices with internet, sensors and hardware to enable sharing of data without human intervention (Navarro et al, 2020). The sensors in Figure 1 detect the physical environmental changes such as humidity and temperature hence relaying electrical signals to re controller. According to research, the sensors send electrical signals to the controller to provide data about the health of crops in relation to the environmental variables such as temperature and humidity in the greenhouses (Navarro et al, 2020). The actuators in Figure 1 receive electrical signals from the controller to produce the desired physical changes that support farming. For instance, the solenoid receive electrical signals from a controller hence creating a medium for the movement of fluids .

The controller in Figure 1 regulates electrical signals from sensors and the data relayed by the actuators. The data from sensors and actuators passes through the controller to the processor where it is processed for sorting and organization before transmission to the cloud server. Part of sorting in the processor includes reducing the size of data by getting rid of unwanted information for the purpose of saving farmers the high transmission and storage costs. The gateways in Figure 1 are important in an IoT smart farm solution system because they transmit data from the processor to the cloud server for storage. These gateways include modems and Wi-Fi that use protocols such as the Message Queuing Telemetry Transport (MQTT) for transmitting agricultural data through the internet to the cloud server for storage (Navarro et al, 2020).

The end users in Figure 1 are farmers who can access the data from the cloud using specific devices controlled by the server. Farmers can install the required IoT applications in the smart devices such as laptops and phones to facilitate easy data collection from the cloud server (Doshi et al, 2019). Therefore, farmers can implement smart farming by using their user devices to collect data from the cloud server regarding environmental conditions for effective decision-making process during production and management of crops. This business report aims at assessing the impact of IoT solution to farming, the already existing components to accomplish the solution, security, ethical and privacy issues.

**Impact of the IoT Solution on the Business (1200 words)**

As businesses continue to embrace technology in their operations, the adoption of IoT has changed different areas of business such as the logistics, production and packaging. The agricultural sector is among the economic fields that have adapted and embraced smart technology in producing food that can meet the growing demand of the increasing global population. IoT smart technologies will be required in a case study by an agribusiness company to solve problems encountered in crop production and livestock management. According to research, the development of IoT solutions for smart crop management has enabled farmers to collect environmental data regarding the humidity, leaf area index and temperature for a better insight on the management and increasing crop yields such as tomatoes in greenhouses (Bauer and Aschenbruck, 2018).

Optimization of irrigation water is a critical challenge to some farmers especially if there is lack of data on factors such as soil moisture content to support crop production despite the ever-changing climate patterns. According to research, small-scale farmers cannot afford the commercial agricultural sensors hence the recent development of low-cost sensor nodes is an effective way of solving irrigation control by enabling farmers to implement smart technologies in managing irrigation (Garcia et al, 2020). These low-cost sensors are essential in recording data such as soil moisture content which can aid in better decision-making when planting crops.

Farmers experience challenges when controlling diseases and may end up counting loses if there is lack of information regarding the type and amount of pesticide to apply in the farms. In a case study by Foughali et al (2018), farmers can enhance their decisions in preventing crop diseases such as the potato late blight disease by collecting data using the newly developed low-cost sensors which transmit data to a cloud server for future retrieval. The data provide farmers with a better approach in managing diseases as compared to the conventional ways of analyzing crop diseases. Another case study proves that the Farm as a Service (FaaS) which is a cloud IoT system was effective in controlling and preventing a strawberry infectious disease known as the *Botrytis cinerea* (Kim et al, 2018)*.*

Livestock farming can be challenging and time consuming especially if the farmers track and monitor the movement of their animals manually since herds move when feeding. According to research, IoT solution for livestock management involves the use of sensors such as the Global Positioning System (GPS) that can relay data on the location of the herds without the need for the farmers to physically control the movement of the animals (Ilyas and Ahmad, 2020). This technique is important in geofencing to ensure the cattle are within the correct boundary location. Confining livestock within a specific area can be a daunting task especially if the number of cattle is high. Technologies such as radio-frequency identification and Low Power Area Network (LPAN) are effective in monitoring the movement of herds and relaying data on the exact location of an animal (Dineva et al, 2021). IoT smart solution for livestock management has also improved communication between farmers which is essential in managing movement of cattle within a specified area. Research proves that farmers use their smart devices which are installed with GPRS sensors which are connected to a satellite for the purposes of communication and livestock tracking (Ilyas and Ahmad, 2020).

Determining the amount of soil nutrients before applying fertilizers can be a daunting task for farmers. The advancement of IoT smart farm solutions has led to the creation of sensors which can detect the presence or absence of nitrogen, potassium and phosphorus nutrients in the soil (Lavanya et al, 2020). Farmers can receive alert notifications in their smart devices which are connected to the sensors to know the type and amount of fertilizers to apply in their farms after testing for nutrients in the soil. According to research, the data recorded by the sensors is transmitted to a cloud database for future retrieval by farmers to support their decision-making processes (Lavanya et al, 2020). This IoT solution controls the use of chemicals and excessive fertilizers that can raise the soil pH hence damaging crops.

Weed control is a challenge to many farmers especially when they cannot clearly identify the type of weeds and depend on manual control methods. According to research, unmanned aerial vehicles (UAVs) are an effective way of detecting the type of weeds in a particular section or entire farm hence farmers can control the devices using remote controllers (Maddikunta et al, 2021). UAVs can collect data on a large area of land hence enabling farmers to save time and the cost of applying herbicides. Research proves that UAVs can spray large pieces of farms by carrying large tanks with capacity of approximately over 5 liters in about 9 minutes per hectare (Radoglou-Grammatikis et al, 2020). Unmanned aerial vehicles are not only effective in saving time and cost but also preventing environmental pollution through application of agrochemicals.

The incorporation of technologies in meeting the world’s high food demand is an opportunity that many farmers continue to embrace due to improved quantities of agricultural produce. Technologies such as Artificial Intelligence (AI) has contributed to the development of Machine Learning techniques that farmers can combine with an IoT cloud-based system to make informed decisions regarding the type of crops to plant or harvest by using algorithms such as Support Vector Machine (Thilakarathne et al, 2022). Farmers can encounter challenges such as improper planning and changing climatic patterns which hinder the accomplishment of agricultural objectives. Research proves that precision farming has enabled farmers to use machine learning technique such as robotics which are programmed to perform human tasks starting from land preparation for planting to harvesting of the crops (Thilakarathne et al, 2022). The agricultural robots function by analyzing data stored in a cloud server to save time and improve the quality and quantity of crops during farm operations such as harvesting.

Smart dairy farming is slowly overtaking the conventional methods to improve the quality of dairy products entering various markets. IoT solutions have enabled dairy farmers to embrace AI technologies such as robotics and machine learning when feeding cattle, processing milk and insemination (Akbar et al, 2020). Traditional methods have contributed to poor decision making processes by farmers due to lack of data to determine the appropriate time to milk cows after calving or determining when the cows are fertile. For instance, it is a daunting task to manually or physically detect and treat cows with a contagious diseases in a herd of cattle hence it is important to integrate IoT smart dairy farming to easily monitor the health of each cow. According to research, farmers can tag the sensor devices on every cow for the purpose of collecting accurate data regarding the cow’s health, milk production, weight, behavioural activity and the fertility state (Akbar et al, 2020). The statistics will provide farmers with better insight regarding what to change or improve for the purpose of increasing milk production. An integration of AI and IoT smart dairy solutions has lowered the labor cost involved in the manual milking of several cows since the introduction of robotics or automated milking systems which have proved to save time and improve milk quality (Akbar et al, 2020).

**Existing components and realizing the innovation (1500 words)**

There are several components of the proposed IoT solution in a case study of an agribusiness company which is striving to improve crop production and livestock management. The proposed solution will have the following components; sensors, drones, raspberry Pi-ES, a base station, gateway based nodes, a Google cloud server and end user devices for the farmer. In a research case study, a raspberry Pi based embedded system (ES) for monitoring environmental factors such as soil moisture content in a greenhouse, is combined with a sensor network comprising of several nodes that collect data which is transmitted online to a website through gateways (Arshad et al, 2020). The sensor nodes and the raspberry Pi-ES will be effective for monitoring temperature, humidity and soil moisture content that will provide farmers with an insight of the type of crops to plant in the business case study. The following components are part of the proposed solution for a farm case study; sensors, a Wi-Fi connection, drones, an IoT base station, gateway, cloud server and services for the farmer (Vasisht et al, 2017).

Each sensor is located at a specific area and records a particular environmental data such as humidity and soil pH, and sending to an IoT base station through the nodes using internet connection. The drones are fitted with cameras effective in monitoring crops and livestock by taking real time aerial photos and sending them to the base station through Wi-Fi connection for analysis (Devi et al, 2020). The drones will be effective in the proposed solution by taking images of crops and livestock for easy monitoring using the raspberry Pi-ES before implementing a decision. According to research, the quadcopter system or drones can be connected to the GPS to spray pesticides or capture images of locations in the farm where the crops are infected by a disease (Devi et al, 2020). The company’s farmers can control the functioning of the drones or UAV using an application in their smartphones. According to FarmBeats case study, farmers control the UAV using the FarmBeats application in their android smartphones (Vasisht et al, 2017).

The IoT base station of the company will receive electrical signals from the sensors and the images taken by the drones for analysis, and sent to the cloud server via a gateway. According to research, the IoT base station which is power-driven by solar panels or batteries has gateway for transmitting data to the cloud and a module for connection to the sensors (Vasisht et al, 2017). The company’s IoT base station will be the controller or processor that receives signals from the sensors and sends the data through a gateway to the cloud for storage. Research proves that the gateways act as data transmission channels from the sensors to the controller and from the processor to the cloud server over a Wi-Fi connection (Navarro et al, 2020). The company’s farmers will access data from a Google cloud server through their smartphone devices for a better decision-making process. The cloud server stores essential data for future reference and allows farmers to access the data through a web service whether they are online or offline (Navarro et al, 2020).

IoT has created opportunities in the agricultural sector with an aim of increasing production to meet the increasing demand of the world’s growing population. However, the implementation of the proposed solution is met with several challenges such as the failure of the sensor nodes to transmit electrical signals when there is especially if the devices use batteries which might be used to power the IoT base station in the absence of solar energy. According to research, batteries are prone to losing power hence hindering the transmission of data from the sensor nodes to the controller (Idoje et al, 2021). The implementation of the proposed solution poses a high risk to data safety due to the increasing cybersecurity issues that can contribute to farmers losing confidential information. Research proves that the application of IoT in farming exposes the data transmission process to cyber-attacks which may cause tempering of information that may lead to the farmers making poor decisions hence causing agricultural loses (Gupta et al, 2020). Hackers can detect vulnerability points at any IoT component and use it to breach data that may cause loss of information hence hindering the implementation of the proposed solution.

The company may integrate the IoT system into crop and livestock management but with the high risk of losing data due to hacking. According to research, the agricultural industry has a high demand for IoT systems with zero possibilities of experiencing cybersecurity issues that contribute to the loss of data (Saha et al, 2021). The company can experience challenges in delayed data transmission due to lack of supporting infrastructure since purchasing or installing additional programs and systems may be costly. Skilled or competent personnel are required to operate the IoT system since farmers may not have the technical expertise to operate the system hence resulting to additional costs that the company will incur. According to research, lack of enough proficient manpower to operate the IoT smart systems is among the main challenges that the agricultural industry has in relation to protecting data (Saha et al, 2021).

The collection of big data by several sensors can contribute to a challenge in implementing the proposed solution since the data have different sources, meaning and format hence the company may not be aware of the standard practices required in the integration of the IoT smart farm technologies and the data. According to research, large data may sometimes have low-quality, fragmented into different meanings; have poor analysis for farmers to easily understand and also farmers failing to comply with the standard data policies (Navarro et al, 2022). Such challenges may hinder the sharing of data between farmers and service providers hence contributing to poor data management and decision-making processes. The implementation of the company’s proposed solution can be hindered by the technical hitches in the IoT systems which are vulnerable to failures of the softwares such as GPS. According to Demestichas et al (2020), many farmers use smart devices which are installed with softwares such as the GPS to direct UAV to monitor crops and the location of livestock hence becoming susceptible to challenges such as missing data on the desired sites due to technical failure of the systems.

The cost of implementing the proposed solution is a factor that the company should consider in their priority list. The IoT smart farm technologies should be easy for the company’s farmers to understand, operate and also affordable. According to research, IoT should be cost-effective and user-friendly to the farmers by enhancing the connection between the various components without high power consumption rates (Vasisht et al, 2017). The proposed solution will have an estimation cost in relation to the evidence-based IoT smart farm technologies with low-cost. In the FarmBeats case study, the company uses TVWS network devices which cost approximately $195 without any extra data charges as compared to other IoT systems which cost over $950 per sensor and an annual subscription charge of about $97 (Vasisht et al, 2017). The company should aim at using the raspberry Pi-embedded system (ES) because it coverts real time analog data to digital form hence contributing to a low-cost IoT smart farm system. Research proves that the low-cost raspberry converts analog data from various sensors and transmitted to the cloud server by means of the MQTT protocol (Hasan, 2020).

The company can implement the cost-effective IoT base station using the photovoltaic (PV) solar panels which convert solar energy to electricity by configuring with batteries or diesel generators. According to research, the configuration of the photovoltaic panels of about 275W with diesel generator (DG) and battery banks (BB) is low-priced compared to a IoT base station using a photovoltaic panel (about 465W) and battery bank (Baidas et al, 2021). Research further shows that the PV and battery bank configuration system requires several solar panels to generate more power as compared to the PV-DG-BB system (Baidas et al, 2021). The company can establish an IoT base station by implementing the PV-DG-BB configuration system which consumes less power hence resulting in low power costs. Research proves that the IoT base stations with the PV-DG-BB for both 275W and 465W configuration system will cost about $210,000 and $213,000 for 72 hours of operation (Baidas et al, 2021).

In terms of the implementation cost of the entire IoT smart farm technology, the agribusiness company will adopt a low-cost evidence-based approach of comparing between three forms of low power wide area Network (LPWA). According to research, the installation cost of NB-IoT is about $ 13,000 whereas the total cost for Wi-fi HaLow and Lora is about $950 because they lack licensing costs as compared to the former which has longer distance coverage hence additional charges (Muteba et al, 2019). The company can use Lora or Wi-fi HaLow type of IoT for farming to avoid licensing cost hence saving more.

**Security Issues to be considered during the implementation** **(400 words)**

There are several security issues that the agribusiness company should take into consideration during the IoT implementation. The company should aim at having a system that can only be accessed by the farmers only. According to research, a multi-factor authentication approach is essential when implementing an IoT system to prevent the hacking possibilities (Rahimi et al, 2022). The company should also test the security software application in the android smartphone devices that the farmers use to confirm the correct devices used in the communication with the IoT. Research proves that, authentication is important before the data transmission between the IoT components (Rahimi et al, 2022).

The company’s farmers should know the areas where security issues can arise in the IoT system. First, there are several methods that cyber attackers can gain unauthorized entry to a network that is not adequately secured, including through unsecured ports, buffer overruns, DoS (Denial-of-Service) and DDoS (Distributed Denial-of-Service) attacks (Mercan et al., 2020). Hackers can then take advantage of unencrypted data, weak passwords, technical glitches with timeout and session management, and an insecure online interface. Some of the security issues for consideration during the implementation of the company’s IoT systems include quality assurance of the smart devices which may pose as a threat to the endpoint security if there is lack of thorough testing of the devices. Several devices are connected over a shared network at once hence making the precise origin of a threat difficult to pinpoint (Mercan et al., 2020).

Developing specialized threat identification modules that assist in identifying weak spots in the agricultural IoT system’s software and hardware is a smart idea. The company’s farmers need to learn how to operate the various software and hardware to control and monitor the IoT system from any location. According to research, farmers need to understand the connection between hardware such as the microcontroller and actuators, and softwares such as the devices’ operating systems and the web IoT page (Rahimi et al, 2022). Nonetheless, this is a crucial security issue to take into account in order to guarantee the efficient operation of the agricultural IoT system. The infrastructure can be made more secure and protected from unauthorized access by attackers aiming to alter the default configuration, get access to data, and cause system disruption by proper hardware setup (Mercan et al., 2020). Another security concern before the implementation of the agricultural IoT system is the lack of data encryption capabilities of the smart devices that farmers use to collect and information regarding climatic and agricultural conditions.

**Ethics and Privacy** **(500 words)**

The company needs to consider several ethical and privacy issues that may impact their proposed business solution. Starting with the ethical issues, collection of data without the users’ consent is among the serious concerns that farmers and consumers of agricultural produce need to understand (Atlam and Wills, 2019). Many sensors used in the IoT system acquire both public and confidential data. The distinction between private and group information must be made apparent and specified in different IoT applications because there are no clearly defined boundaries for user information. All the farm activities and data are embedded within the IoT system hence a data breach of the system can affect all the farmers using a specific IoT network (Atlam and Wills, 2019).

In the context of privacy, the IoT system is prone to the identification of the company’s details due to the data transmission between the hardware (sensors, actuators, controller, and gateway) and softwares (cloud, web IoT platform and operating system). According to research, the users of an IoT platform can use smart-lock or fingerprints to prevent unauthorized persons from accessing their confidential data (Mercan et al., 2020). The company can use an authentication verification system such as a two-step verification to ensure they are the only individuals who can access the IoT platform (Chaudhry et al, 2021).

IoT system can contribute to profiling or exposure of a farmer to other users without their consent especially if there are several people using the same browser or device. Lack of appropriate policies that control the access and transmission of data in IoT smart farm systems has contributed to farmers’ unwillingness to share their confidential data with other third parties (Wiseman et al, 2019). Life-cycle changes are not frequently encountered because most consumer goods that contain private information, such smartphones, cameras, and laptops, are controlled by the same owner for the duration of their entire lives (Atlam and Wills, 2019). But, as several objects from daily life become connected and start to hold personal information, the risk of privacy exposure due to ownership changes will rise.

The company needs to focus on improving the protection of its big data by implementing the encryption approach. According to research, the encryption enhances the sharing of information between the identified users whereas the decryption is useful in recovering data in the absence of internet access (Amiri-Zarandi et al, 2022). The company can also store their data in the cloud server and encrypt the information to ensure that user can access the data by a search. Research proves that the cryptographic algorithm is effective in arranging the encrypted data which is stored in the cloud into different files (Amiri-Zarandi et al, 2022). The company can use this approach to ensure that only the farmers and researchers can use the authentication keys to access data hence lowering the possibility of a cyber-attack. In the context of the IoT for agriculture, the integration of several companies will create a more diversified and decentralized system, increasing system complexity and decreasing transparency in data gathering operations.

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