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FOG COMPUTING AND IoT BASED MODERN AGRICULTURAL SYSTEM

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ABSTRACT

With the current development in information and communication technology (ICT), Internet of Things (IoT) and Fog computing, small and smart devices enter people's daily life to enhance the quality of life by reducing hard work. As a growing agriculture trend, a smart agricultural system using IoT enables smooth and intelligent interaction between the computational components and agricultural devices and modernization of agriculture. To support smart agriculture systems, cloud resources are usually explored to process the sensing data from agriculture devices. However, the high quality-of-service (QoS) of agriculture systems challenges the unstable and long-delay links between cloud data center and agriculture devices. To face this issue, fog computing, or mobile edge cloud computing, which pushes the computation resources onto the network edge (e.g., cellular base station), and IoT, which connects various sensors or devices with the Internet, sprouts as a promising solution. We are thus motivated to design a fog computing and IoT based modern agriculture system model.

KEYWORDS

Fog, Cloud, IoT, delay, Modern Agriculture.

1. INTRODUCTION

Fog computing and internet of things (IoT) are two new emerging technologies in the information technology (IT) industry. The internet of things (IoT) is the most wanted technology in this era. Worldwide spending on the Internet of Things (IoT) is forecast to reach \$745 billion in 2019 which was \$646 billion in 2018 according to a new update to the International Data Corporation (IDC). IDC expects worldwide IoT spending to sustain a compound annual growth rate (CAGR) of 15.4% through the 2017-2022 forecast period surpassing the \$1 trillion mark in 2021 and reaching \$1.1 trillion in 2022 Luiz et al., 2017.

Modern agricultural system is one kind of Cyber-Physical System (CPS) emerge as engineered system that offers integrations of computation, networking and physical processes, enabling unbroken interaction between cyber services and physical elements Khaitan et al., 2014. Building on the discipline of computing, sensing, communication and embedded system technologies will gather data sensed by various sensors then transfer the data to the fog node containing summarized database where data will be analyzed and make a decision for the agricultural system. IoT applications and services are generally backed up by server ends deployed in the cloud promising solution to provide services to the end-users with elastic resources at low cost as smart devices are generally inadequate in computational power, battery, bandwidth and storage Jeba et al., 2019. However, cloud computing cannot solve all problems due to its own drawbacks such as unacceptable latency, lack of mobility support and

location-awareness Shanhe et al., 2015. To solve these issues the new technology, fog computing, is emerged.

The worldwide population will touch 8 billion people by 2025 and 9.6 billion people by 2050 according to the Food and Agricultural Organization of the United Nation (FAO). So, food production must increase by 70 percent by 2050 globally Kiran et al., 2015. Thus, to face challenges of food production, we need to develop methods to produce more output with the limited available natural resources. IoT and fog computing both can be used to increase the quality, quantity, sustainability and cost effectiveness of agricultural production. The high quality-of-service (QoS) of agriculture systems challenges the unstable and long-delay links between cloud data center and agriculture devices which can be obtained using fog computing.

In this paper, Section 2 discusses related works. Section 3 describes the system design and methodology. The simulation result is discussed in Section 4. At the last, Section 5 concludes our work and suggests future work.

2. RELATED WORKS

The smart agriculture system based on cloud computing and IoT was proposed by Tongke et al., 2013. Here the architecture for the smart agriculture system was presented based upon the concept of cloud computing and IoT. The author provides the idea of building a plant factory and automatic control production but didn't propose a model of how data would be sensed, analyzed and delivered to the fog node for computing and

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decision making. To achieve the dynamic distribution of resources and balance of the load was combined by agriculture information cloud.

The authors of Ji-Chun Zhao et al., 2010 represent an internet and wireless sensor networks based monitoring system considering the applications of IoT in agriculture. An information management system was designed which can deliver data for research in agriculture. They also developed field monitoring (e.g., data acquisition about the fields, data processing models, and system configuration module) software providing accurate control for the monitoring of the greenhouse.

The challenges of IoT technology and the possible future applications are discussed in Agrawal et al., 2011. The authors discussed some key challenges (privacy, security, authentication and identification, trust and ownership, integration, coordination, and regulation) of IoT applications. They also urged that the gap between theoretical and real-world implementations of IoT applications would be reduced by using RFID (Radio Frequency Identification), Wireless Sensor Network (WSN) and mobile communication technologies.

The authors of Chen et al., 2011 proposed IoT based 'Digital Agriculture'. The working process of the digital agriculture is divided into two phases. Firstly, sensors collect information about the temperature, the soil contents, the wind, etc. Secondly, the collected information is transferred with ZigBee. The agricultural product is labeled with EPC code which is read by EPC code reader.

A management model based on IoT for visualization and traceability of agricultural products is presented by Zhou et al., 2010. The purpose of the proposed model was to ensure food demand and promote sustainable development of modern agriculture. The products' logistic information along with the Internet of Things (IoT) is used by the authors for effective product supply chain management.

Ashkan et al., 2018 introduces the minimization of delay in IoT using a service delay model. The advantage of this scheme is that it is not confined to any particular architecture (like a cellular network) and IoT, fog, cloud nodes are not bound to be of any type or capacity. This framework works by allowing fog nodes to cooperate to fulfill the request sent from IoT by load sharing. They also designed a request load processing with IoT and fog node. Decision to offload a task is based on factors like amount of computation need to perform on a task, queuing status and processing capability of a fog node. Reachable table is used to find the best fog node which comprises of the least propagation time and estimated waiting time. Authors describe different policies for exchanging request among IoT nodes, fog nodes and cloud nodes those can influence to minimize the delay.

3. SYSTEM DESIGN AND METHODOLOGY

3.1 Fog- IoT

Fog computing, also known as fogging or fog networking, is a decentralized computing architecture in which the computing resources, both hardware and software, are distributed in the most logical, efficient place between the things generating data and the cloud. Fog computing is an extended version of cloud computing and services to the edge of the network, pushing the power of the cloud closer to where data is created and acted upon. The core idea for designing fog computing is to decrease the data transportation which is processed, analysed and stored to the cloud and improve efficiency. Besides, there are also some other reasons (security performance, business logic etc.) to use it Crosser et al., 2017. A simple three level hierarchy is assumed in our fog-cloud system. Each edged device is connected to a nearby fog device in this framework. Fog devices are interconnected and each of them is linked to the cloud Fan et al., 2017. Finally, fog computing can process and lessen data size at a very early stage, thus minimizing delay and save bandwidth as increasing production in the industry.

The network of hardware, software, sensors, actuators, vehicles, water supply system, mechanical and digital machines, home appliances and other things embedded with electronics, and network connectivity that are provided with unique identifiers which qualify these objects to connect and to operate particular programs and realize remote control is called Internet of things (IoT). The internet-based equipment, concentrated management and control of machines can be realized by the main computer and improved production and life through more detailed and dynamic means. It is beneficial for synchronization between human beings and the physical world and is considered as the third wave of information industry development with the computer, physical equipment, and internet Cao et al., 2010. RFID, sensor, sensor network and internetwork communication are the major technologies of IoT which all are involved in IoT industrial chain, namely, identification, sensing, processing and information delivery (Hong et al., 2011).

The intelligent technology IoT is a combination of identification, sensing and intelligence. Life and even intelligence of life itself can also be considered as part of IoT technology. Pattern identification fields like measurement and computing as well as computer and communication fields like sensing, communication, information collection and processing use it Tongke et al., 2013. Fog computing has changed the definition of IoT. IoT and Fog are strongly related with each other. Therefore, IoT can be defined as IoT= Fog Computing + Ubiquitous Network + Intelligent Sensing Network. Fog Computing and related data are the most important for fog computing management platform. It includes management of accession of cloud computing customization application by users of IoT, computing and processing what is involved in customization service; organizing and coordinating service nodes in the data center AR Shovon et al., 2018. Ubiquitous network includes 3G, LTE (Long-Term Evolution), GSM, WLAN (wireless local area network), WPAN (wireless private area network), WiMax, RFID, Zigbee, NFC (near field communication), Bluetooth and other wireless communication protocol technology, optical cable and other wire communication protocol, and technology Cai et al., 2012.

3.2 System Architecture

The system architecture is divided into four layers: input layer, storage layer, analysis layer and instruction layer shown in the Fig. 1. (Hori et al.). First two layers are in user end and the others layers are the part of fog computing end.

Figure 1: System Architecture

3.2.1 Input Layer

The internet of things (IoT) technology with regards to smart farm produce mainly consists of soilless culture and culture solution control technology, growing environment control technology (carbon dioxide density, humidity, wind pressure and speed), artificial photosynthesis technology, intelligent irrigation technology, etc. IoT technology and method are used in farm produce production with plant factory

technology as integration. This layer also may be called as sensing layer made of atmosphere testing sensor, biosensor, RFID and GPS work together for sensing of information in the cultivation process. The lighting sensor can show the distribution of real-time intensity of light and video sensor observes the growth of the plant as well as the size of the plant. By using the information of sensors, we can know about the growth of plants whether it is a germination period, growth period or other. We can also know the health condition of a plant by spectral analysis of plant photos.

3.2.2 Storage Layer

The sensing data are stored which are obtained from various sensors or camera in agricultural database in the user end to visualize the current condition of plant. The storage layer send the collected data to the network edges to analysis. This layer is responsible for reliable delivery and to display terminal. The process delivery uses 3G wireless broadband, 2.5G CDMA, and 2G GPRS as well as multi-media techniques to acquire a remote connection Tongke et al., 2013.

3.2.3 Analysis Layer

Analysis layer is the most important layer in which delivered data are analysed according to the analysed result from the data warehouse in the cloud. It analyses huge amount of data to extract useful information for optimal farming. Analysis can be performed in different ways such as correlation analysis, monitoring for hostile sign (forecast and avoid risks based on past experience), fault detection (detect outsiders objects in the plots) Hori et al., 2010. Analysed database or agricultural knowledge database used for making instructions.

3.2.4 Instruction Layer

This layer provides some useful instruction to the user end to perform optimal farming. Instruction set may include work guidance (Fertilizer, water, daniel, crop), work plan preparation (draw up optimal work plan), farm checks etc.

3.3 Modern Agriculture System

The control architecture of modern agriculture based on fog computing and IoT is shown in Fig. 2. This data center Xing et al., 2012 made of control and database. The control platform also consists of agroecological environment control, agriculture resource control, farm produce and food safety, production process control, agricultural tools and facility. The data center consists of a computer system and other facilities (communication and memory system) go with it. It also includes redundant data communication links, environment control facility, monitor facility and different kinds of security devices. A smart agriculture model is shown in Fig. 3. The agroecological environment control subsystem comprises water quality monitoring, automatic improvement of water quality. Proper fertilization saves fertilizer and monitors soil ingredients, soil humidity, light, wind, air, etc.

The agricultural resource control subsystem comprises an intelligent greenhouse that permits automatic adjustment of temperature, water irrigation that can automatically control flow and save water, scientific disease and pest monitoring.

Figure 2: Control architecture of modern agricultural system based on fog computing

Farm produce and food safety subsystem involves: Get informed of the entire logistics process, rationally arrange storage in warehouse, traceability system of farm produce supply chain.

Agricultural equipment and facility subsystem comprises: Analysis of farm machinery breakdown, remote control of farm machinery, operation

monitoring of farm machinery. Various subsystems of modern agriculture system such as agriculture environment controller, production process controller, food safety agricultural resource are controlled by summarized knowledge base in the fog node. Data from central data warehouse may also be used to control subsystem if data is not exist in the knowledge base.

Figure 3: Modern Agriculture System based on fog-cloud

3.4 Analytical Model

The analytical model is introduced to evaluate the service delay of the proposed framework.

3.4.1 Service Delay

After processing the request in IoT nodes, send that request to a fog node or a cloud node.

Definition 2: Service delay is the time required to be performed a task. It can be defined as the summation of propagation time, processing time and waiting time of a request.

Thus, service delay d_i for IoT node j can be written as:

$$d_i = P^C + D_{pj} + W_j \quad (1)$$

$$d_i = P^F + D_{pj} + W_j \quad (2)$$

$$d_i = P^{FC} + D_{pj} + W_j \quad (3)$$

Where P^C propagation time of j^{th} request when the IoT node sends it's requests directly to the cloud layer. P^F propagation time of j^{th} request when the IoT node sends it's requests directly to the fog layer. P^{FC} propagation time of j^{th} request when the IoT node sends it's requests to the cloud layer via fog layer. D_{pj} processing time of j^{th} request and W_j is waiting time of j^{th} request.

3.4.2 Propagation Delay

In Equation (1) the term P^C refers to propagation time to send IoT node's request directly to the cloud layer. This term is effective when the request is heavy or has to be sent to the cloud for archival purposes, or when there is no fog layer and the IoT node communicates directly to the cloud. This term can be defined as:

$$P^C = \frac{\delta + \sum_{k \in S} \delta_c}{c} \quad (4)$$

Where δ is the distance between IoT node and cloud node. δ_c is the inter cloud distance. S is total number of cloud node and c is the propagation speed.

In Equation (2) the term P^F refers to propagation time to send IoT node's request directly to the fog layer. This term is effective when the request is light or has to be sent to the fog for archival purposes, or when there is no

cloud layer and the IoT node communicates directly to the fog. This term can be defined as:

$$\mathbf{P}^F = \frac{\delta_f}{c} \quad (5)$$

Where δ_f is the distance between IoT node and fog node. Here, we assume the inter fog node distance is negligible. c is the propagation speed.

In Equation (3) we have the IoT-fog-cloud delay term $\mathbf{P}^{FC}$ when the IoT sends its requests to the cloud via fog layer. This term is effective when the request has to be sent to the fog or to the cloud node depending on the request type, or when all the fog nodes are busy then IoT node communicates directly to the cloud. This term can be defined as:

$$\mathbf{P}^{FC} = \frac{\delta_f + \sum_{k \in S} \delta_{fc}}{c} \quad (6)$$

When the request type is heavy.

$$\mathbf{P}^{FC} = \frac{\delta_f + \sum_{k \in S} \delta_{fc} + \delta_{fc}}{c} \quad (7)$$

When the request type is light.

Where δ_{fc} is the distance between cloud node and fog node. Here, we assume the inter fog node distance is negligible. c is the propagation speed.

3.4.3 Processing time

In the Equation (1), (2) and (3), for the request j , the processing time or processing delay can be defined as:

$$D_{pi} = P_j = (aP_{j-1} + b) \bmod m \quad (8)$$

Where P_{j-1} is initial processing time. P_j is current processing time. It will generate a sequence between 0 and m , where $0 < m < 4$. a and b are integer constants.

3.4.4 Waiting time

In the Equation (1), (2) and (3), for the request j , the waiting time or waiting delay can be defined as:

$$W_j = \sum_{l=0}^L P_l \quad (9)$$

Where W_j is waiting time of j^{th} request. L is the length of queue of the fog or cloud node in which the request is inserted. P_l is the processing time of the l^{th} request in the queue.

4. RESULTS

In this section we evaluate the proposed model through simulation. Each sample point in the graphs is obtained using 100000 requests using simulation. The network topology is designed with 5000 IoT nodes, 100 fog nodes, and 3 cloud servers. If an IoT node generates type Light request between the IoT node and its corresponding fog node is assumed to be through IEEE 802.15.4 with transmission rates 250 Kbps. If an IoT node generates type Heavy request between the IoT node and its corresponding fog node is assumed to be through IEEE 802.11a/g with transmission rates 54 Mbps Ashkan et al., 2018. Assumed Simulation parameters are mentioned in the Table 1.

Table 1: Main Parameters of the simulated nodes

Device Type	CPU (GHz)	RAM (GB)	Delay (ms)
Cloud Node	3.5	8	100
Fog Node	2.67	4	50
IoT Node	1.8	3	30

The simulation result of fog computing based modern agriculture system is depicted in the fig. 4. The allocated workload and service delay time is

represented in the x axis and y axis respectively. It is shown that the service delay rate of the system is more increasing when the workload is more than 5000. However, when the workload is more than 6500 then the requests would be out of process as the threshold is 2 unit second.

Figure 4: Simulation result of fog based agriculture system

Figure 5: Simulation result of cloud based agriculture system

Figure 6: Simulation result of fog-cloud based agriculture system

Figure 7: Comparison among fog, cloud and fog-cloud system

The simulation result of cloud computing based modern agriculture system is depicted in the figure 5. The service delay rate is higher than the fog based system. The more time is required to perform a task. However, no request would be failed. All the requests would be processed in the cloud server.

The simulation result of fog-cloud computing based modern agriculture system is depicted in the Fig. 6. It is the combination of fog and cloud computing. It reduces service delay time than cloud based system but slightly greater than fog based system. Here, the failed requests in fog based systems would be processed in the cloud. So, no request would be lost and increases the performance of fog based agricultural system. Hence, it is understandable that the fog-cloud based model is better than only fog or only cloud based model shown in fig. 7.

5. CONCLUSION AND FUTURE WORK

In this paper, we proposed a modern agricultural system model based on IoT and fog computing which reduces the service delay using fog instead

of cloud computing. It also enhances performance using fog-cloud instead of fog computing. Combination of fog computing and IoT is more suitable in Wireless sensors and Actuators Networks (WSANs) because fog computing reduces delay than cloud computing shown in result. A resource pool integrates the hardware equipment in Agricultural Information Network (AIN). In a modern agriculture, a huge amount of data attained by Radio-frequency identification, wireless communication, automatic control, data sensing processes of IoT are controlled with Agricultural Information Cloud (AIC). We will work in future on "Data protection model of Fog-IoT based Smart Agriculture System".

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