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Design and Simulation of Fog Computing Model for Smart Farming

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Abstract:- Smart farming is an innovation in the agricultural sector that can improve the performance of the agricultural industry with more automated and data-driven farming methods that connect with the IoT devices in the farming area. The fast spread of connectivity has given rise to IoT-based agricultural management solutions. Most of the existing farming systems, which are designed using the traditional cloud computing architecture, are unable to handle massive volumes of data produced by the connected IoT devices and may have high latency upon heavy traffic. Consequently, it is preferable to bring the data processing closer to the source of its production in order to minimize the latency and network usage in assisting real-time decisions based on the data generated. This shows the deployment of application modules is important for the efficient utilization of network resources. For this reason, fog computing model has been proposed in this paper to solve such deployment issues. The architecture is to be designed for smart farming, and simulated using iFogSim, which enable to evaluate the usage of bandwidth and computing resources as well as latency. The performance results obtained by the proposed fog computing approach are to be compared to those of cloud-only implementations in order to give recommendations for practical use.

Keywords:- *Smart Farming; Fog Computing; Cloud Computing; Ifogsim; Module Mapping.*

I. INTRODUCTION

Agriculture makes a significant contribution to the development of financial resources for many countries. Food production challenges are becoming significant since it is anticipated that the population growth will be increased to 9 billion in next thirty years. Thus, it becomes apparent that the requirement for the utilization of techniques and advanced technologies for reacting to the requests of the populace and, simultaneously, confronting the difficulties inborn in the labor reduction the use of innovative technology applied to agriculture is a typical practice that adds to another idea designated smart farming. In this case, smart farming is related to the incorporation of information and communication systems along with other technologies into the production of agriculture, such as information management systems, sensor networks, data analysis, and communication networks. These systems and technologies are applied to various applications in the agricultural section, for example, fertilizing, crop monitoring, soil management, and monitoring of water resources and management.

The Internet of Things (IoT) is a network of physical devices, mobile devices, and other objects that are embedded with software, sensors, actuators, and network connectivity to collect and exchange data.

Today, the number of IoT devices is significantly expanding and an enormous number of data streams are generated by these devices from farming for processing. Cloud computing can support here by offering on-request adaptable storage capacity and processing services that can scale the requirements of IoT. Howe, latency-sensitive IoT services involve real-time data processing, which is difficult to achieve with a cloud server because of high communication latency. The forthcoming IoT system challenges the architecture of traditional cloud computing.

To solve these problems, and meet scalability, proficiency in network processing, and latency-sensitive communication, the requirements of IoT applications have prompted the development of the fog computing paradigm. Fog computing is the layer between the cloud and edge devices, and used as an effective paradigm for reducing latency by provisioning virtualized computational, storage, and networking resources closer to the edge where the data is consumed [1]. Hence, the fog computing is attempted to solve such a scenario in this research.

II. LITERATURE REVIEW

This section discusses the research works related to applying fog computing in smart farming systems. Concerned with it, Ashkan et la., present a service delay model for IoT, cloud, and fog applications and the minimization of delay in IoT [2]. This system has the benefit of not being restricted to a single architecture, and IoT, fog, and cloud nodes do not need to be of any specific capabilities. This framework operates by allowing fog nodes to contribute in order to meet IoT requests via load sharing.

In processing the sensing data from agricultural devices, the resources are required to analyse. The quality of service of the systems faces with the ambiguous and delays from devices to the data centre. Therefore, in [3] the authors proposed a modern agricultural system model based on IoT and fog computing which reduces the delay and enhances the performance using a fog computing model instead of the cloud computing model.

In [4], the purpose of the authors is to protect the damage of many different insect pests in the tomato crop field with the use of various sensors that provide real-time in the field. With the use of fog computing and smart sensors, the farmer can collect the pest data in the field and alert the pest existence in the early stages with the alert message.

The authors in [5] propose the two-tier Fog computing based IoT framework. The two fog layers perform different individual tasks according to the capabilities of computation. The authors emphasized how this fog computing manages to lessen the number of transmitted data to the cloud by a significant quantity.

From these research works it is learned that the deployment of fog computing is not explicitly applied to smart farming. For this reason, this research is intended to apply fog computing in smart farming and design especially for it.

III. THE PROPOSED MODEL

For filling the research gap, the architecture comprising three layers of computing is proposed to apply in the area of smart farming as in fig 1.

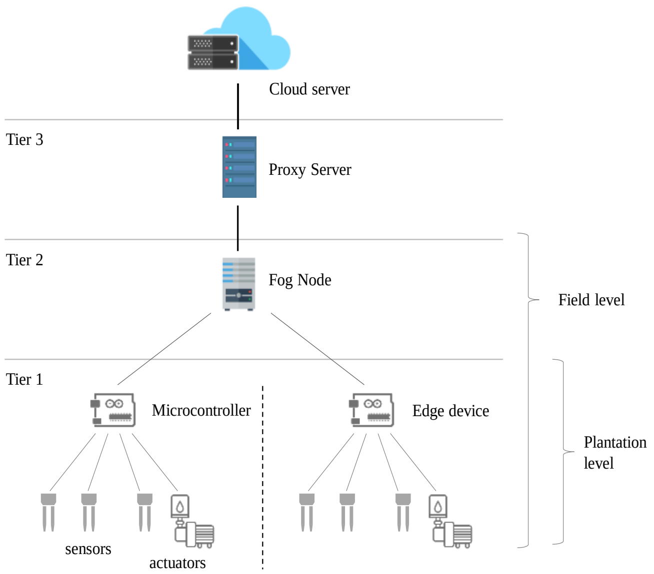

Fig. 1. The proposed three-layer architecture for smart farming

The first layer is the plant level which integrates edge devices including sensors like soil moisture sensors and actuators such as water pumps. Here soil moisture sensors and pumps are used for demonstration only. For practice use, other sensors and actuators can be added. Multiple soil moisture sensors are deployed in the plantation area to cover all the field areas. These soil moisture sensors are responsible for estimating the amount of water in the soil. When the soil moisture sensors detect the deficiency in water and minerals, the water pumps automatically switch on and supply water to the plants in the field area.

The second layer of the system is a fog node which is linked to edge devices with micro-controller. The fog node acquires the data from the sensors and processed them for further analysis. The uppermost layer is a cloud server that is virtual machines in data centre, and is connected to a fog node through a proxy server and has a significantly higher of resources for storage and management. A proxy server connects to the fog layer and facilitates data flow to the cloud server and vice versa. Fog nodes provide forwarding of the processed data and alerts from all the field areas in the lowermost layer to the cloud server for storing the data. Furthermore, data stored at the cloud can be retrieved at any moment.

A. *Application Model*

Based on this architecture, the application for smart farming is typically modelled using as a Directed Acyclic Graph (DAG) as in Figure 2, in which the vertices represent the various modules of the application, and the edges represent the data dependencies between modules. These modules perform processing upon incoming data, and the edges connect the output of one module to the input of another module.

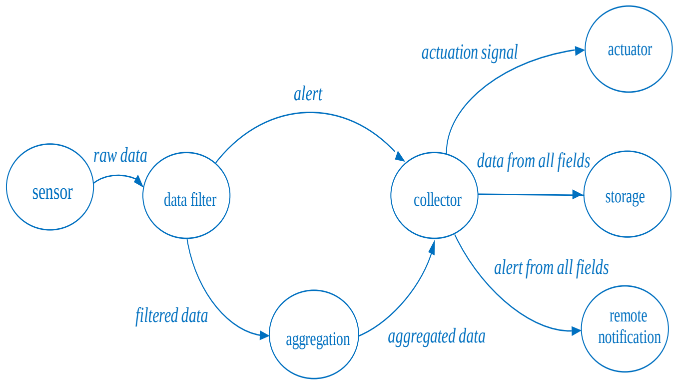

Fig. 2. Application model for the proposed smart farming system

The application is designed in such a way that the proposed smart farming system is driven by five application modules; filtering module, aggregation module, collector module, storage module, and a remote notification module. The filter module is the initial interface to the soil sensors. It continuously reads the raw sensor data streams and discards the data which are out of range or have sensor errors. In the event of abnormal conditions, it activates the output devices and the alert data is forward upstream to the collector module for further processing. The data after being acquired by a sensor is transmitted to the aggregation module and collector module. The aggregation module receives the filtered data and performs data compression to reduce the traffic load. The collector module receives the reduced data from the aggregation node as well as alert data from the filtering module and forwards them to the storage module or remote notification module. The storage modules receive all the data collected from each field and store them for further analysis or processing. Upon

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receiving alerts, the remote notification module performs functions to notify the abnormal conditions of the remote users.

B. Simulation Environment for the Proposed Application Model

Since the fog computing environment consists of IoT devices, fog nodes, and cloud, real-world implementation of the environment is very costly. In this case, simulation toolkits can be helpful and provides frameworks to design customized experiment environment. Thus, to evaluate the performance of proposed application model for smart farming architecture using fog computing in the index of execution time, energy consumed, network usage, and processing delay, the model is developed simulation environment.

For this purpose, iFogSim simulator is used as the simulation tool as it allows the placement of service, network infrastructure, and resource allocation policies for fog computing.

Developing the model in iFogSim requires three components to be defined; physical, logical and management components. Physical components contain network physical devices which are arranged in hierarchical order. Each fog device is created with specific instruction processing rate and power consumption attributes that reflect its capability and energy efficiency. Logical components consist of application modules and application edges, and these components can be logically characterized by the application running in the fog computing architecture. Management components are controller and module mapping objects. The controller object dispatches the AppModules on the allocated fog devices following the placement information given by the module mapping object, and conducts the resources of fog devices.

At the completion of the simulation, the controller object accumulated the aftereffects of cost, network utilization, and energy utilization on the cloud, which are useful for assessment of performance of fog computing approach.

IV. EXPERIMENTAL SETTINGS

The application model for smart farming is developed in such a way as required by the three components of iFogSim for smart farming. To compare conventional cloud computing approach and proposed fog computing, both of them are developed for smart farming, simulated and then compared each other. Figure 3 depicts the topology using cloud-only deployment developed in iFogSim. In this case, IoT devices connect directly to cloud.

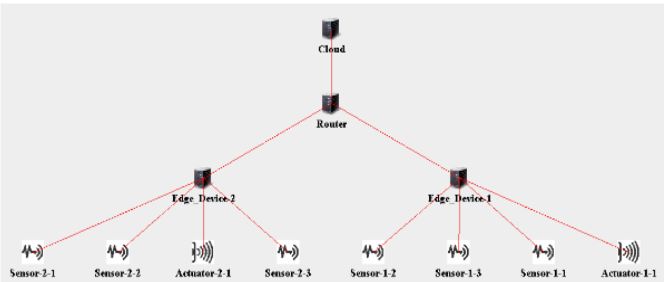

Fig. 3. Topology for cloud-based deployment

In the case of fog computing approach, fog device is added between edge and cloud layers to help the processing load handled by the system, as in Figure 4. Both figures show only one sample topology of two edge devices and one fog node among the five topologies used in experiments.

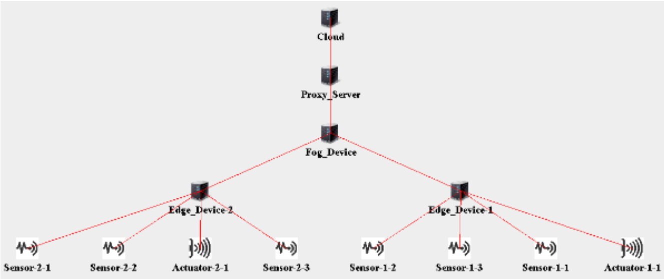

Fig. 4. Topology for fog-based deployment

In simulation, to evaluate the impact of increasing number of edge devices and fog devices, the following topologies are used to test in both deployments as stated in Table I.

TABLE I. TOPOLOGIES USED IN THE TESTS

Network Topology	Number of edge devices	Number of edge devices
Topology 1	1	2
Topology 2	1	4
Topology 3	1	8
Topology 4	2	4
Topology 5	2	8

After defining the topologies, each device is needed to define parameter for its computational capability. Table II shows important parameters values used in simulation, such as upstream and downstream capacity, RAM and MIPS.

TABLE II. DEVICE COMPUTATIONAL PARAMETERS

Devices	Capacity (Mbps)		RAM (GB)	MIPS
	Upstream	Downstream		
Cloud	1000	10000	40000	44800
Proxy Server	1000	10000	4000	40000
Fog Device	1000	10000	4000	2000
IoT Device	100	10000	1000	500

Furthermore, the simulation toolkit allows for the modelling of network link latency between the devices, as presented in Table III.

TABLE III. NETWORK LINK PARAMETERS

Source	Destination	Link Delay (ms)
Cloud	Proxy Server	100
Proxy Server	Fog Gateway	25
Fog Gateway	Edge Device	2
Edge Device	Sensor	1
Edge Device	Actuator	1

The simulations are performed for three different application models intending to represent different load conditions from low-intensity traffic to high-intensity one. In the case of farming, low traffic load occurs at night-time when environmental changes are light while the heavy traffic load occurs mostly at daytime when drastic changes of environmental conditions are likely to occur.

Table IV describes the characterization of application attributes in terms of tuple CPU usage in MIPS, network capacity in Kbytes, and inter-arrival time in milliseconds, generated from environmental sensors in the case of farming.

TABLE IV. APPLICATION CHARACTERIZATION

Application Type	CPU (MIPS)	NW (Kbytes)	IA (ms)
Low Traffic	500	5000	1000
Medium Traffic	1000	10000	100
High Traffic	2000	20000	50

V. RESULTS AND DISCUSSION

After assigning parameter values in devices for each topology, both smart farming with cloud- only method and fog deployment methods are simulated in iFogSim. Network usage, execution time, and the average application latency are the crucial considerations and experimentation on various configurations has been carried out to assess the efficiency of the system.

A. Analysis of Network Usage

The first parameter to be measured is the network usage. The simulation results of the two deployment methods under three application cases are presented in Figure 5 through 7.

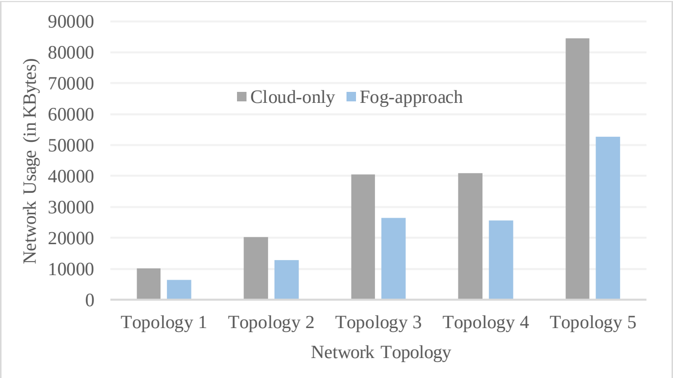

Fig. 5. Network usage upon low traffic load

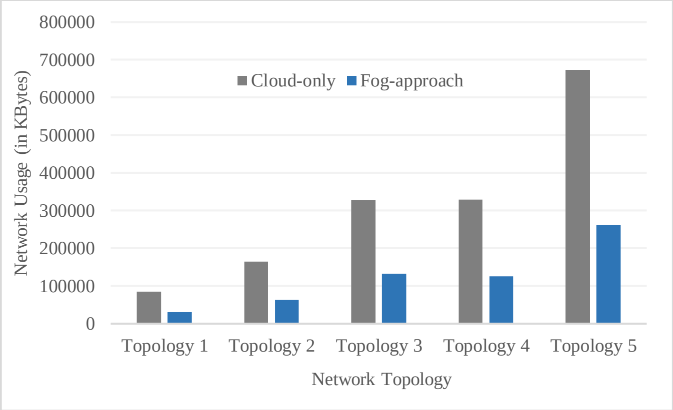

Fig. 6. Network usage upon medium traffic load

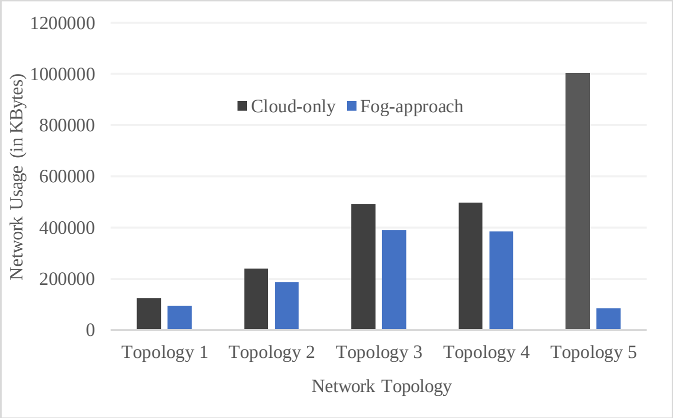

Fig. 7. Network usage upon heavy traffic load

It is learnt that the number of devices connected within the application significantly increases the load on the network in both methods, but lower usage is needed to handle that load in fog-cloud method. In the case of cloud-only method, the rapid growth in network usage can delay the application performance by causing network congestion. To avoid such issues, it is apparent to employ fog-based execution models since data is pre-processed at the source and there is no need to transmit data frequently.

B. Analysis of Execution Time

Also, the results of execution time in both methods are presented in Fig 8, 9 and 10.

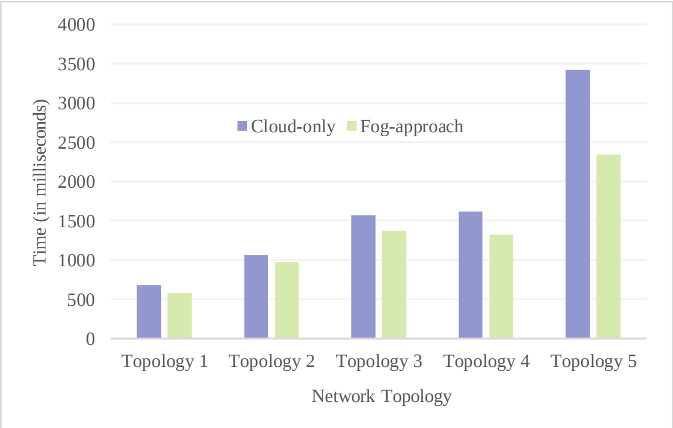

Fig. 8. Execution time upon low traffic load

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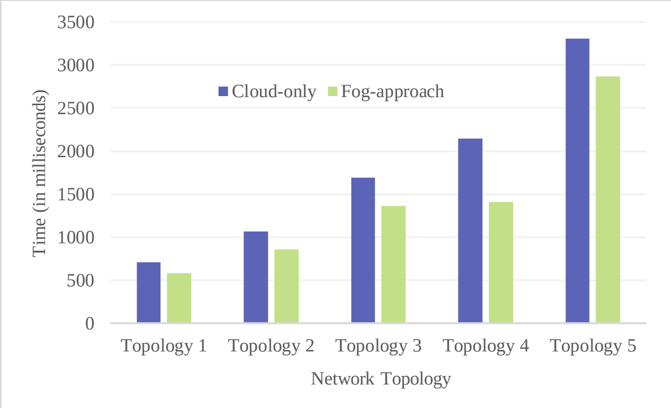

Fig. 9. Execution time upon medium traffic load

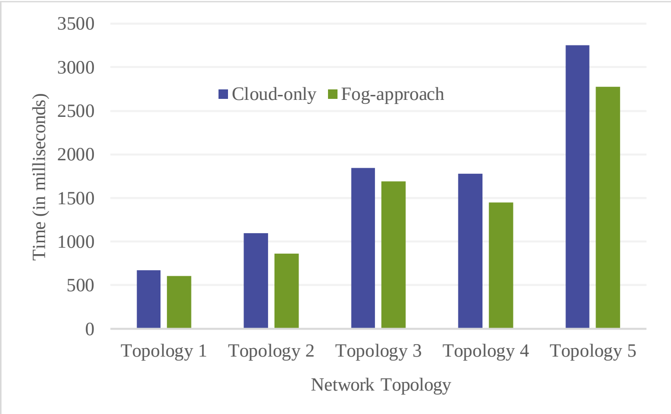

Fig. 10. Execution time upon high traffic load

The results about execution time show an increase in the number of devices results in higher execution time, and thus increasing transmission rate at the same time. In this comparison, fog computing performs better than the cloud-only design.

C. *Analysis of Application Latency*

Another requirement in real time processing is the latency, which is the fundamental consideration for applications which decides high performance of that application. The simulation results of average latency measurement in each application are described in Figure 11.

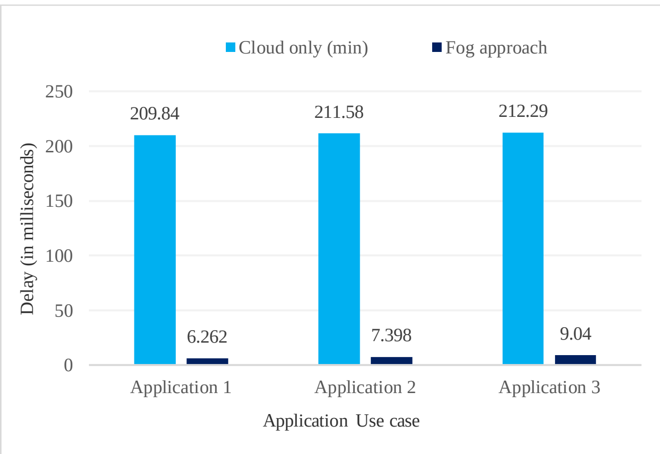

Fig. 11. Latency in each application use cases

From the measurements, it is clear that the latency is low in applications running fog computing. The reason comes from the fact that data from the soil moisture sensors are delivered to the fog nodes, which are dedicated to the farming areas with sufficient computational capacity to handle the data from the field area and send the actuation signal to the water pump in a shorter amount of time. In addition, the fog-based results show a significant reduction in network use due to network congestion control.

VI. CONCLUSION

Fog computing has become increasingly important in recent years, particularly in time-sensitive application fields. The demand for faster responses has increased as the number of data-generating devices has raised. For that reason, application with fog computing has been applied to solve such issues. The reason why fog computing has the advantages is that it enables traffic to avoid frequent cloud access and perform computations at the edge of the network, resulting in a rapid response back to the client device and minimizing the average latency of the control loop. This is the reason why smart farming system has been designed and simulated in iFogSim to compare its performance over cloud-based implementation. Although there is a cost for setting up a fog node to handle data requests, the simulation results show that fog-based design always excel in performance indices than does a traditional cloud-based design. As the application is intended to serve geographically distributed clients with low application latency and real-time responses, it is ideal to choose a fog-based architecture for the agricultural applications.

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