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A Cloud Computing Architecture with Wireless Sensor Networks for Agricultural Applications

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ABSTRACT

The emergence of precision agriculture has been promoted by the many developments in the field of wireless sensor actor networks (WSAN). These WSANs provide valuable information for harvesting, work management, growth of crops, and prevention of crop diseases. This paper focuses on introducing cloud computing as a new approach to be used in addition to WSANs to further enhance their application and benefits to the field of agriculture.

Keywords: *Component, Wireless Sensor Actor Networks, Cloud computing, Percision Agriculture.*

1 INTRODUCTION

Lower productivity in agriculture is often cited as one of the major problems faced by most of the developing countries. Many issues associated with agriculture can broadly be divided as issues related to environment monitoring and control of green house. These issues play a major role in the enhancement of the productivity and prevention of diseases in the crops.

Most of the agricultural practices in developing countries are sub-optimum and continue to be traditionally carried out with unskilled laborers who are commitment to the traditional knowledge and reluctant to innovate. In-depth research in this area is still lacking. This situation makes it necessary to think of building a decision support system for agriculture with information support by experts. In this paper, an effective approach to overcome some of the issues related to agricultural productivity is presented. The proposed approach involves using wireless sensor actor networks (WSANs) in combination with cloud computing services to help farmers optimize the use of available resources in their agricultural tasks.

This paper is organized as follows: Section 2 gives an overview of related work; Section 3 presents the architectural model for agricultural WSAN linked to cloud computing system; and finally conclusion is given in Section 4.

2 RELATED WORK

Researchers worldwide have investigated the adoption of Wireless Sensor Network (WSN) technology and cloud computing in the field of agriculture. Green house monitoring and control based on TINI embedded web server unit which collects the data and routes it from local sensor networks to a base station has been studied and experimented by Stipanicev [1]. Monitoring of greenhouse environment by using a WSN has reported by Ahone [2]. Kang [3] has proposed an automatic greenhouse environment monitoring and control system model. A decision support system called iFARM, useful for precision agriculture is described by Yassine Jiber in [4].

Micro-electro-mechanical systems (MEMS) have gained increasing attention during the recent years. MEMS facilitate the development of smart wireless sensor actor networks (WSAN). The main activities of the sensors are to sense and measure the environmental data from the fields and process the data with the help of decision making unit for actuating the process. Sensor nodes that sense the data of the environment and a group of actor nodes which act according to the decision taken by the decision making system linked together by wireless medium are known as wireless sensor actor networks [5].

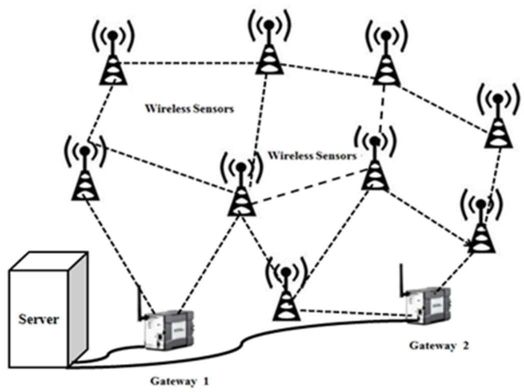

Fig. 1. WSAN Architecture

Figure 1 shows a typical WSAN architecture as described in [6]. Here, sensor nodes and actor nodes communicate wirelessly with the gateway node or main node. The data gathered by sensor nodes are then forwarded to the main node, which acting as a bridge or gateway then forwards the data to the cloud via a server for storage of data. The cloud can then evaluate and analyze the data and determine a suitable action to be taken by actor nodes.

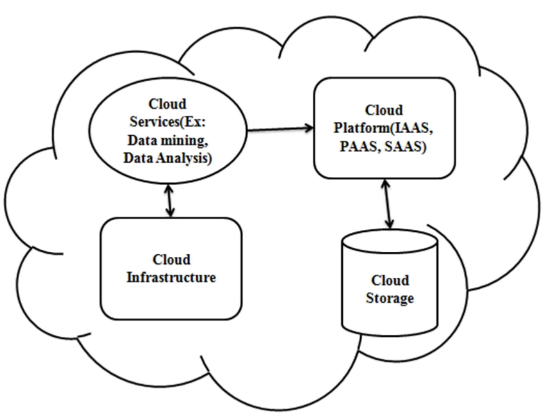

Fig. 2. CLOUD Architecture

Figure 2 represents typical cloud architecture and its components. Cloud computing architecture comprises the components and subcomponents requireed for cloud computing. The main elements in the architecture are a front end platform, a backend platform, a cloud- based delivery mechanism and a network.

A. Cloud based delivery

Three of the most basic cloud computing models are:

- *Software as a Service (SAAS):* It includes the ICT working environment tools such as software, web applications etc., without buying/downloading and installing in specific machines. Another characteristic of this model is that the users are charged for whatever has to be used for a specific duration, against the traditional way of buying and paying for the full application such as "3.5-inch disk drive".
- *Platform as a Service (PAAS):* It provides clients with the computing platform for designing and developing specific applicat-ions with minimum redundancy. It also takes care of hosting of those applications without concerning about hardware and data storage requirement. It also guarantees the availability of most recent platforms and their security.
- *Infrastructure as a Service (IAAS):* This model usually includes tangible as well as intangible components used in availing ICT services, such as virtual computers, traffic monitoring and redirecting, basic network components etc. This is the most prominent benefit of cloud computing as the organizations invest the most in establishing infrastructure.

The five major benefits of cloud computing are:

- Reduction of initial cost
- Allocation of resources on demand without any limit
- Maintenance and up gradation performed in the back end
- Easy rapid development including collaboration with other systems in the cloud
- More possibilities for global service development

3 DATA ANALYSIS AND DISCUSSION

Cloud computing combined with the Internet offers resources and services at a lower cost which is attractive l for farmers working at cultivation lands. The proposed architecture offers expert services to the farmers regarding cultivation of crops, pricing, and fertilizers to be used etc. at an affordable price. Agricultural cloud service framework at SAAS layer supports various services to the farmers to interact with cloud by using any inexpensive interfaces to request for information and to access it quickly even free of cost from free services.

An agricultural cloud service [7] can use existing cloud infrastructures such as networks, servers etc., other than the resources discussed below in Figure 3.

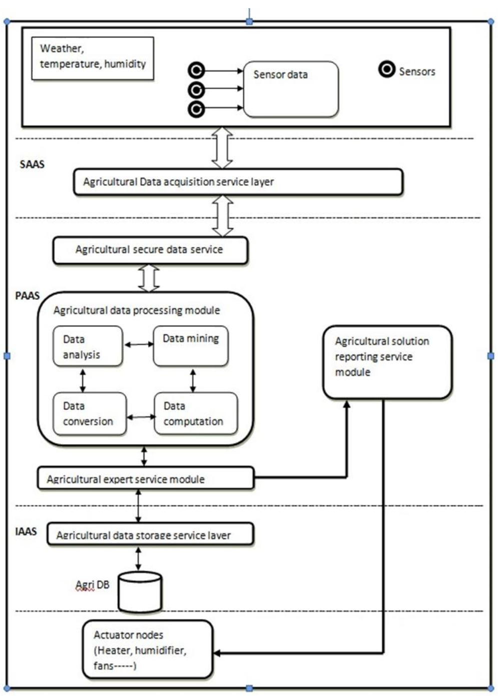

Fig. 3. Agricultural WSAN Cloud

The layered architecture shown in Figure 3 contains 3 groups:

A. Sensing group

B. Cloud service group

C. Actuator group

These groups are briefly described below:

A. Sensing Group*:* The sensing group consists of various sensors for checking temperature, humidity, pressure, etc. These sensors collect real time data from the field and forward the sensed data to sensor data storage unit which in turn forwards the data to the cloud for further processing.

B. Cloud Service Group*:* The cloud service further contains the following layers:

1. Agricultural-Data Acquisition Layer (ADAL)
2. Agricultural-Data Processing Layer (ADPL)
3. Agricultural Data Storage Service Layer (ADSSL)

a) *Agricultural-Data Acquisition Layer (ADAL)***:** It uses the Internet to provide services to be used by farmers and agricultural experts to add or query data by using their applications service interfaces such as browsers, tablet PCs, sensor (RFID) devices or mobile devices. The ADAL, deployed as SAAS in Cloud, provides various interface services to be used by different types of consumers with different devices. ADAL services layer is mainly used for agricultural data acquisition and to supply solutions to users.

b) *Agricultural Data Processing Layer (ADPL):* It is a data processing layer with libraries that accept data in various formats from different devices and convert them into uniform formats. It performs computations on large data sets and reports to consumers of agricultural-cloud platform as a service. It also encapsulates a layer of software and provides it as a service that can be used to build higher-level services. ADPL, deployed as **PAAS** in an agricultural-cloud, contains library modules to be used to build high-level agriculture- based applications. ADPL provides services that contain libraries for data security, data processing, expert decision making, and data reporting.

ADPL may be further divided into following modules:

- Agricultural-Secure Data Service (ASDS) Module
  ADPL uses ASDS libraries to provide authentication, integrity, and secrecy for incoming data from various sources.
- Agricultural-Data Processing Service (ADPS) Module

Agricultural-Data Processing (ADP) service contains libraries for analysis and conversion of data from various devices into uniform format.

- Agricultural-Expert Service (AES) Module
  This expert service layer contains libraries which enable providing of solutions or decisions after processing sensing group data.

- Agricultural-Solution Reporting Service (ASRS) Module.
  This contains libraries which provide reporting service to customers in formats required by them.

c) *Agricultural-Data Storage Service layer (ADSSL):* This layer supports a database infrastructure facility for storing large quantity of data required in agriculture sector for results to be accurate. ADSSL is deployed at IAAS level in cloud which allows data sharing and usage. Agricultural data base contains Agricultural-Expert knowledge Database (AKDB) which contains rules and inferences required for decision making.

C. ***Actuator Group***: The actuator group consists of set of actor nodes which will act on the environment based on the decision given by decision unit. The controllers in the actor nodes receive digital data from the cloud and generate action commands. The analog signals resulting from the action commands are sent to the hardware devices to perform the intended actions.

4 APPLICATIONS

WSANs combined with cloud computing may be applied to tackle many problems related to agriculture. As examples, three major applications are presented below:

A. Image processing of diseased plant

In this application, the user can take a picture of the diseased plant and can upload to the PAAS layer of the cloud computing system where the platform as a service module is equipped with the high end image processing unit. The picture in color form can be converted to grayscale and pixel format for processing to eliminate unwanted noise with the help of Gaussian noise removal algorithm. The resultant picture can be checked with the normal healthy plant image. A pixel to pixel comparison can be done to extract texture features. Finally, based on the texture and color features, a solution can be determined and sent to the actuating group to perform the required action. A flow diagram for these operations is depicted in Figure 4.

B. Prediction of Diseases

In this application the sensor group senses the various factors like temperature, humidity, soil density, water content in soil, and other parameter required for healthy growth of a plant in the sensing environment, and forwards the data to the cloud for processing to predict any diseases.

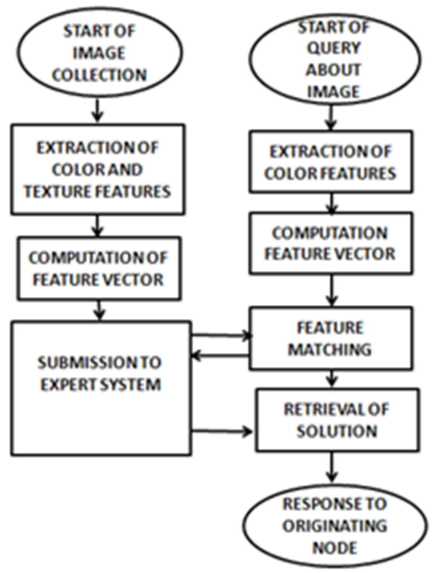

Fig. 4. Processing diagram

The advanced artificial intelligence module in PAAS predicts any impending diseases based on the current values of the parameters. For example, certain diseases such as rice blast disease for rice plant, occur based on the temperature and humidity factors of approximately 0.85 and 0.92, respectively. Now, if the sensing group finds that the temperature and humidity values are around 0.82 and 0.89, respectively, a warning message about a possible disease is sent along with any remedial measures to be taken to the actuator group.

C. Controlling of the Culturing Environment.

In this application the growth conditions for normal growth. of a plant are maintained by controlling the plant culturing environment. For example, factors best suited for the growth of tomato plants are heat, nutrition, light and water. The effective temperature for tomato plants is 55-

85°C and 5-6 hours of effective light. They require considerable amount of water, but should not be over-watered or drowned. Also, if the temperature goes beyond 85°C, then the automated cooling system which is the part of actuating group should control the temperature so that plant will not spoiled by overheat. Similarly, if the plant is suffering from the lack of water, then the automated watering system should irrigate the plants with the required amount of water.

5 CONCLUSION

The use of WSAN and Cloud services in agricultural field provides high potential benefits which are economically worth in the field of agriculture. In this paper we have proposed and outline an agricultural WSAN Cloud for providing assistance to farmers during crop cultivation. Farmers can receive at an affordable price the information about soil condition, crop cultivation environment, crop diseases, and pricing solutions during cultivation through the expertise available in a cloud computing system. As a part of future work, a prototype model of the system is planned.

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