13 A Survey on the Integration of Internet of Things and Cloud Computing for Precision Agriculture

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13.1 Abstract

During the recent decades several sectors of production and services have been benefitted from the rapid development of Information and Communication Technologies (ICT). The integration of these technologies in the agricultural sector within the grounds of Precision Agriculture is of particular importance and concerns significantly the scientific community, as it is considered to be among the most innovative methods of agricultural practice, being directly related to the productivity improvement and sustainable development. In particular the integration of Internet of Things (IoT) in agriculture, through the automation and total digital management of agricultural production using Wireless Sensor Networks (WSN) in order to acquire and monitor data concerning the cultivations, as well as through the employment of Cloud Computing applications for transferring, storing and processing these data using the Internet, is without any doubt an innovative research field. In this paper an attempt is made to review scientific approaches as well as research practices regarding the integration of Internet of Things on the grounds of Precision Agriculture, focusing particularly on the study and examination of real applications needs in agriculture with regard on Cloud Computing engineering technologies.

Keywords: Precision Agriculture, Internet of Things, Cloud Computing, Wireless Sensor Networks

13.2 Introduction

The implementation of technologies which provide reliable, cheaper and user friendly ICT tools in agriculture is a major asset for its sustainable growth. Smart Agriculture solutions enable more efficient operations and management of resources in agricultural production by interconnecting the areas of Management Information Systems (MIS), Precision Agriculture (PA) and Agricultural Automation. In particular, Precision Agriculture (PA) is a whole-farm management approach which aims in improving agricultural production by maximizing the efficiency inputs and minimizing their environmental impacts in terms of sustainability [see P1]. For this purpose in Precision Agriculture innovative techniques are applied, involving informatization, satellite positioning data, remote sensing and proximal data gathering.

13.3 IoT and Cloud Computing for Precision Agriculture

Although Internet of Things (IoT) and Cloud Computing technologies share several complementary characteristics [see F1], they have developed separately during the past years. At present an innovative IT approach is gaining ground according which these two complementary technologies are combined, offering in this way a great number of benefits [see P2].

Internet of Things (IoT)	Cloud Computing
Diffusive (things placed everywhere)	Ubiquitous (resources usable from everywhere)
Real World Things	Virtual Resources
Limited Computational Capabilities	Virtually Unlimited Computational Capabilities
Limited Storage	Virtually Unlimited Storage
Internet as a Point of Convergence	Internet as a Service
Big Data Source	Big Data Management

***Figure 1**: Complementary Characteristics of Internet of Things and Cloud Computing [F1]*

Agricultural Informatization, through the integration of Internet of Things (IoT) and Cloud Computing may bring revolutionary changes to agriculture, through the automation of the entire agricultural production. A primary reason for adopting these technologies in Precision Agriculture is to facilitate the storage, management, access and dissemination of information which are required to support farmers in decision making and strategy planning so as to achieve efficient management of resources and higher cultivation production.
Some of the most essential features of Internet of Things (IoT) and Cloud Computing for Precision Agriculture [see P3] are:

- Data Acquisition and Remote Storage
- Low-cost Access to ICT Resources
- Online Agriculture Expert Consultation
- Land Records Automation
- Weather Forecasting

13.4 Typical Framework of IoT and Cloud Computing for Precision Agriculture

The integration of the Internet of Things (IoT) and Cloud Computing technologies for Precision Agriculture, through the automation and digital management of the entire agricultural production is an innovative research field. According to a typical framework for integrating these two technologies in agricultural applications [see F2] the management platform, which is the “core” of the Cloud and Data Storage, involves the users’ access to the application interface, the computing and processing of the customization services as well as the organizing and coordinating of the service nodes in the data center. The essential networking services are provided in ways that ensure the efficient and secure transfer of the acquired data through RFID, Wireless Sensor Networks (WSNs), gateways or cloud proxy machines. The wireless network communication is established by applying protocols and standards such as Zigbee, LoRaWAN, LPWA, Bluetooth, Wi-Fi, as well as GPRS/3G/4G, whereas optical cable and other wire communication protocols and technologies may be applied as well. Any additional communication required may be established in service-oriented methods via messaging applications [see P4].

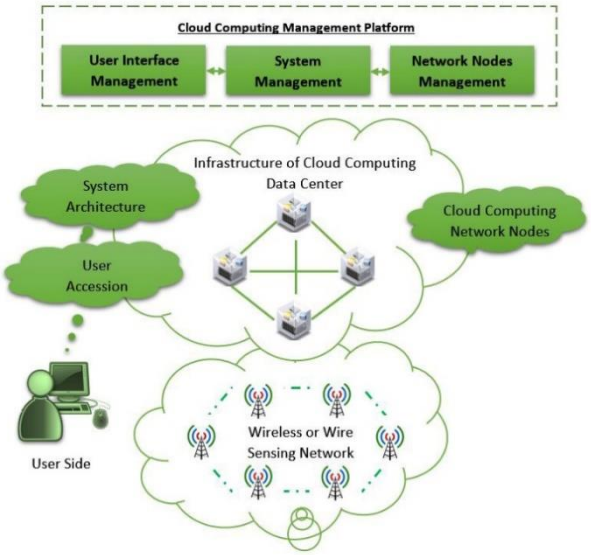

***Figure 2**: Typical Framework of IoT and Cloud Computing for Precision Agriculture [F2]*

13.5 Examples of IoT and Cloud Computing Applications for Precision Agriculture

Several Internet of Things (IoT) and Cloud Computing applications for the needs of the agricultural sector have been developed and introduced during the past few years, some of which are briefly overviewed as following:

- Concept Model of Mobile Cloud Computing (MCC): Mobile infrastructure which employs application features and services designed to be user friendly providing farmers with extended and seamless functionality despite any limitations of mobile devices resources [see P5]. This application employs simple handheld devices such as laptops, tablets and smartphones which support Wi-Fi, GPRS, 3G or 4G technologies [see F3].

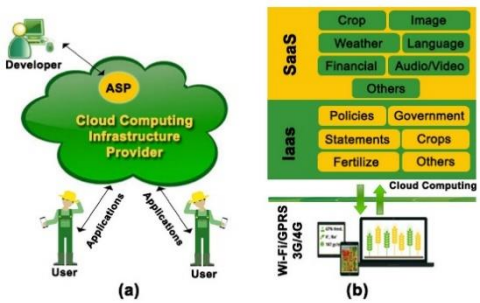

***Figure 3**: Concept Model of Mobile Cloud Computing (MCC) [F3]*

- Wireless Sensor Actor Networks (WSANs) with Cloud Computing Services: It integrates Wireless Sensor Actor Networks (WSANs) with Cloud Computing Services [see F4]. In this application environmental data are acquired by sensors and are processed with the aid of a Decision Support System (DSS). Sensor nodes which acquire environmental data and a group of actor nodes which operate according to the decision taken by the DSS, are interconnected with wireless medium [see P6].

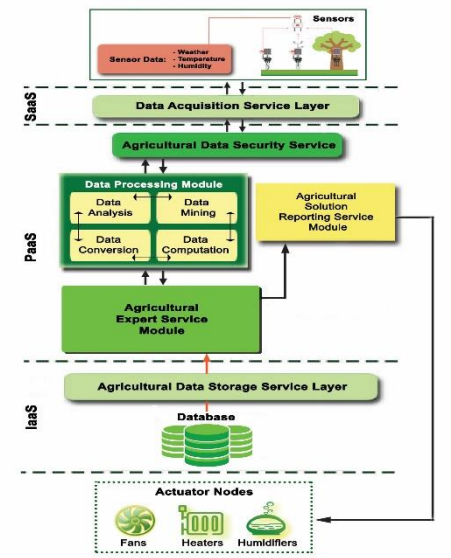

***Figure 4**: Wireless Sensor Actor Networks (WSANs) with Cloud Computing Services [F4]*

- Agriculture Production Process as a PDCA Cycle: Primary sensing and knowledge management techniques are used to provide cloud services. In this application production data are routinely collected whereas analysis engines analyze the stored data and provide advice and suggestions about the agricultural production [see P7].

13.6 Benefits and Challenges of IoT and Cloud Computing for Precision Agriculture

The integration of Precision Agriculture with innovative technologies such as the Internet of Things (IoT) and Cloud Computing can give a strong impetus to the entire development of the agricultural sector in terms of sustainability. In particular, the implementation of these technologies in Precision Agriculture presents the following advantages [see P8]:

- Better and more efficiently organized information resources are guaranteed as the management of data is performed by the service providers.
- Information can be accessed by stakeholders at any time or location through the e-data bank databases.
- The communication and interaction among stakeholders worldwide is effortless, fast and secure.
- The requirements in maintenance infrastructure are significantly reduced as all technical issues are in the responsibility of service providers.
- Due to the fact that all communication attempts are result oriented, farmers, companies and researchers are motivated to involve more into the field of Precision Agriculture.
- The problem of rural-urban migration and unemployment can be reduced as services are provided remotely at any time.
- Due to the mass involvement of different stakeholders, cloud-based IoT applications in agriculture can boost sustainable growth and economic development.

Despite the fact that the agricultural sector may be greatly benefited by the adoption of the Internet of Things (IoT) and Cloud Computing technologies, their actual implementation seems to be precocious as usage in the open fields is mostly focusing on simple applications. Considering the present conditions, some challenges and concerns are to be encountered about the efficient integration of the Internet of Things (IoT) and Cloud Computing technologies in agriculture:

- Simplify the usage of present applications and make them cost-effective in order to be user-friendly and affordable for the majority of farmers

- Establish a certain degree of homogeneity and interoperability among all data and devices through open source technologies for standards, applications and platforms, specially addressing to the requirements of Precision Agriculture.
- Provide wireless communication in rural areas by establishing broad, reliable, constant, high-speed and low-cost network coverage.
- Establish constant interaction with third party data-bases containing information about soil, water and air data, insects and pest control, meteorological history and forecast, satellite imagery, logistics and retail analytics etc.
- Minimize the high extent of computer illiteracy in rural areas by providing appropriate training.

13.7 Conclusions

The future growth of agriculture depends on the adaptation of cutting-edge technologies which focus on farmer needs such as the Internet of Things (IoT) and Cloud Computing. The implementation of such technologies supports the agricultural community in terms of accessibility and affordability.
The integration of the Internet of Things (IoT) and Cloud Computing technologies in Precision Agriculture provides a flexible regulatory environmet for services and innovations leading in this way into the automation of the entire production through Integrated Farm Management.

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