Review on the Trends and Challenges of Cloud Computing Technology in Climate - Smart Agriculture

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Abstract. Climate-Smart Agriculture is an approach for guiding actions required to help stakeholders around the world, identify and develop strategies in order to make agriculture more productive and sustainable. Cloud computing, as a trend of future information technology applied in various fields, may play a significant role in agricultural informatization by bringing some new prospects to information management and service. Evolving cloud computing technology in agriculture is an extensive opportunity to carry out industry agricultural applications aiming in the development of services in rural areas. Agriculture, and especially climate-smart agriculture, is a field which is benefited with the applications of cloud computing with regard to resources sharing, cost saving and efficient agro systems construction. The purpose of this survey is to examine the technological background of cloud computing, as well as to review its applications in agricultural informatization, focusing particularly on the trends and challenges regarding the field of climate-smart agriculture.

Keywords: Climate-Smart Agriculture, Cloud Computing, ICT, Information Management.

1 Introduction

The sector of agriculture is going to face enormous challenges as, according to Food and Agriculture Organization of the United Nations (FAO), the total agricultural production should be increased by 60% in order to meet all nutritional needs of the constantly growing world population. This goal has to be achieved despite the impacts of climate change in global agricultural production and the fact that many of the resources required are already stretched (70% of the world's fresh water supplies is consumed for agricultural purposes). Moreover, taking into consideration the land

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use change emissions, it is estimated that the agricultural sector, generates about one-quarter of global greenhouse gas emissions (FAO, 2013).

Climate-Smart Agriculture (CSA) is an approach for guiding actions required to help stakeholders, from local to national and international levels, identify and develop strategies in order to make agriculture more productive and sustainable. CSA provides the means to relate actions both on-farm as well as beyond the farm, by incorporating elements concerning policies, institutions, investments and technologies as following (FAO, 2013):

- Farm, cultivation and livestock management for handling resources efficiently as well as increasing production and resilience.
- Ecosystem and landscape management in conserving ecosystem services that are essential in order to increase resource efficiency and resilience at the same time.
- Services for farmers and land managers so as to enable them to implement changes which are necessary for the efficient management of climate risks/impacts and mitigation actions.
- Changes which enhance the benefits of CSA in the wider food system, including value chain interventions as well as demand-side measures.

One way of addressing these issues and increase the quantity together with the quality of agricultural production is by using cutting edge technologies in order to establish more "intelligent" and interconnected farms through agricultural informatization.

As far as agricultural development is concerned, the implementation of Information Communication Technology (ICT) is a major asset for the sustainable growth in agriculture. In past few years, the research focused on agricultural infrastructure development and information service. In order this situation to be changed and promote a rapid development of agricultural informatization, it is essential to apply technologies which provide reliable, cheaper and user friendly ICT tools in agriculture.

Cloud computing, as a trend of future information technology applied in various fields, may play a significant role in agricultural informatization by bringing some new prospects to information management and service. Evolving cloud computing technology in agriculture is an extensive opportunity to carry out industry agricultural applications aiming in the development of services in rural areas.

Meanwhile, the innovative technology of the Internet of Things (IoT) is highly related to cloud computing as IoT acquires compelling computing tools through cloud computing and cloud computing encounters the optimum channel of practice based on IoT. Thus, the integration of these technologies, using Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSN), for data acquisition and monitoring corresponding to cultivations, as well as cloud computing applications for transferring, storing and processing these data using the Internet, is predicted to bring revolutionary changes to agriculture, through the automation of agricultural production.

The study of cloud computing in agriculture is of important theoretical and practical significance. The purpose of this survey is to examine the technological background of cloud computing, as well as to review its applications in agricultural informatization, focusing particularly on the trends and challenges regarding the field of climate-smart agriculture.

2 Overview of Cloud Computing Technology

Cloud Computing, often referred to simply as "the cloud", has been characterized as "the fifth utility service", along with water, electricity, gas, and telephone, for it provides readily available on demand computing services, similarly to any other utility service which is available in modern society (Buyya et al., 2009).

Although the popularity of the term "Cloud Computing" was launched in 2006 when Amazon.com introduced the first widely accessible cloud computing service under the name of "Elastic Compute Cloud- EC2", it could be argued that as a concept it has emerged since the 1960's (Kleinrock, 2005; Armbrust et al., 2009; Wheeler and Waggener, 2009).

As it appears from literature there are various perspectives concerning the definition of "Cloud Computing" (Staten, 2008; Vouk, 2008; Armbrust et al., 2009; Buyya et al., 2009; Plummer et al., 2009; Vaquero et al., 2009; Mell and Grance, 2010) among which, the most recognized and generally accepted is the one stated by Mell and Grance on behalf of the U.S. National Institute of Standards and Technology (NIST). In particular, according to NIST, Cloud Computing is defined as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction".

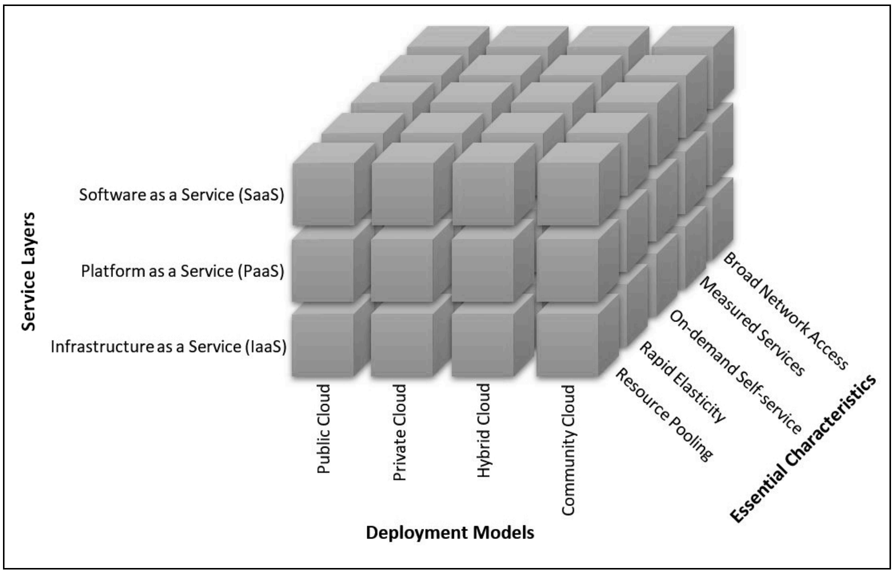

Fig. 1. Anatomy of Cloud Computing according to NIST (Craig-Wood, 2010).

Moreover, NIST suggests that the anatomy of Cloud Computing consists of five essential characteristics, three service layers, and four deployment models as shown in Fig. 1 (Mell and Grance, 2010).

Preferably, a cloud should involve all of the five essential characteristics, while as far it concerns the four deployment models, public cloud is the one that "cloud computing" has been initially referred to and is most commonly used. The other deployment models constitute variations of the public cloud, sharing similar characteristics and service layers (Rountree and Castrillo, 2014). The three service layers refer to the services offered by the cloud providers and are described depending on user requirements as following:

a) Infrastructure as a Service (IaaS): Due to recent developments in network management and virtualization, cloud infrastructure provides processing, storage, traffic monitoring and re-directing, as well as other forms of lower level hardware and network resources in a virtual way via the Internet network. These resources are offered upon the demand of the end user and are charged per use, differentiating from traditional hosting services in which physical servers or parts of them, are offered and charged on a periodical basis (Leavitt, 2009; Rountree and Castrillo, 2014). Moreover, end users have control over operating systems, deployed applications, storage, and in some cases limited control over selected network components (e.g. host firewalls), without the need of managing or controlling the underlying cloud infrastructure (Mell and Grance, 2009). Some researchers suggest to further divide IaaS into Hardware as a Service - HaaS and Data as a Service - DaaS (Wang et al., 2008), but it is more common for IaaS to be regarded as a whole concept.

b) Platform as a Service (PaaS): This service layer is more advanced than the IaaS one, for it acts as an integrated design, development, testing, and deployment platform and provides the end user with programming and execution environments such as operating systems, programming languages, databases, and web servers. End users are given the ability to develop their own applications directly onto the cloud infrastructure, after creating them by using programming languages and APIs supported by the provider. In addition, end users have total control over their deployed applications without being responsible for the management or control of the underlying cloud infrastructure such as network, servers, operating systems or storage (Mell and Grance, 2009). This kind of approach reduces most of the system administrative responsibilities (e.g. setting up and switching among development, testing and production environment) that are traditionally assigned to the developers, enabling them to concentrate on more productive issues. (Lawton, 2008). Finally PaaS carries some other appealing features including embedded instruments for measuring the deployed applications usage for charging purposes as well as established online communities for cooperation, interaction and problem solving purposes (Rountree and Castrillo, 2014).

c) Software as a Service (SaaS): Through this service end users are provided, upon their demand, with complete turnkey solutions of software applications or even more of sophisticated systems, such as CRM or ERP, directly via the Internet network (Leavitt, 2009). These kind of solutions are hosted as services in the cloud and are delivered via browsers, correspondingly to user subscriptions. SaaS is also characterized by a multi-tenant architecture according which, all users share a single code base maintained by the provider. Authorization and authentication security policies are employed in order to guarantee the partition of user data. Due to this sharing mechanism the cost of the services provided is far more appealing compared to the traditional off-the-shelf and bespoke ones (Wang et al., 2008). Such an approach eliminates the workload of installing, running, as well as maintaining applications on local computers and reduces the cost of software purchases due to on-demand pricing policies.

Summing up, cloud computing is designed to integrate a perfect system, which is able of distributing high computing power to the end users by combining computer, storage and network technologies (including grid, distributed, parallel and utility computing) with regard to load balance and reutilization (Ding and Yan, 2012).

3 Cloud Computing Technology in Climate - Smart Agriculture

Cloud computing is a cutting edge technology which has great impact in climate-smart agriculture as it provides efficient management of resources and higher production by facilitating the storage, management, access and dissemination of information. Furthermore, a primary reason for adopting cloud computing in agriculture is to support farmers in making decisions and drawing strategies related to cultivations.

3.1 Features of Cloud Computing in Agriculture

A brief overview of the features provided in agriculture through cloud computing technology is presented as following:

- *Data acquisition and remote storage*: Several of the available data acquisition tools, such as Radio Frequency Identification (RFID) sensors and Wireless Sensor Networks (WSN) can be effectively integrated with cloud computing applications for temperature humidity, luminosity, soil moisture monitoring, etc. (Hori et al., 2010). Moreover cloud computing provides high storage capacity suitable for the backup of such large scale of data and information relevant to cultivations, offering in addition a suitable infrastructure for decision support as well as mutual information and experience sharing among the worldwide agricultural community (Feng, 2010).
- *Low-cost access to ICT resources*: Cloud computing provides access to extensive ICT resources which are offered upon the demand of the user and are charged per use. In this way farmers can access the required resources on-demand from the cloud, instead of investing in owning expensive ICT hardware infrastructure (Prasad et al. 2013).
- *Online agriculture experts consultation*: In the situations when farmers are not able to solve any occasional problems they may face at the different stages of agricultural production, cloud computing offers a sufficient alternative, as online expert advice could be found in the repository of the cloud databases. Therefore, farmers could face any problem instantly, as they receive immediate and accurate respond (Wenshun, 2011).

- *Land records automation*: Due to the accessibility of large scale storage infrastructure, land records are being digitized world-widely. Cloud computing storage facility offers a feature of entering and storing a land record along with any descriptions which are relative to that particular region, such as production history, soil analysis result, etc. Various public or private operators are responsible of the data accuracy after the proper verification of facts and figures (Hori et al., 2010).
- *Weather Forecasting*: Cloud computing may provide farmers with weather forecast and analytics for specific time periods so that they can take decisions related to cultivations (TongKe, 2013).

3.2 Applications of Cloud Computing Technology in Agriculture

In literature there can be found various applications of cloud computing technology designed to meet the needs of agricultural sector. Some of these applications are briefly overviewed as following:

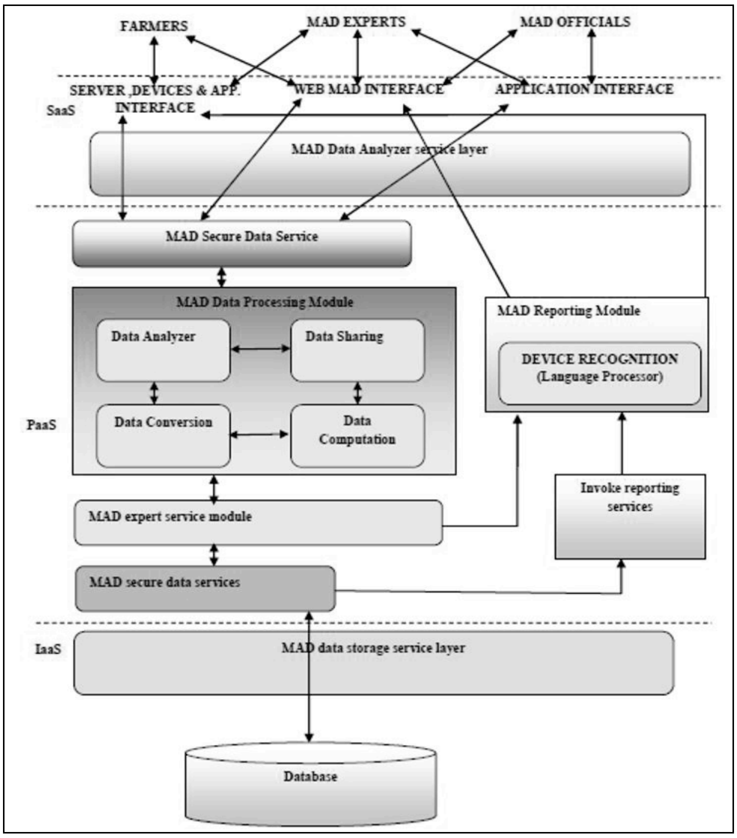

Fig. 2. MAD-framework Architecture.

a) Agriculture cloud based on MAD-Cloud architecture: It offers specialized services to farmers regarding crops cultivation, fertilizers usage, pest control, etc. In addition, researchers in the field of agriculture can access the cultivation history of multiple regions and add their suggestions regarding innovative agricultural techniques. Last but not least, existing cloud infrastructures like networks, servers etc. can be used and various services are supported regarding the interaction with the cloud by using IoT features such as sensors, mobile devices, GPS etc. MAD-cloud framework as shown in Fig. 2 is based on a layered architecture consisting of three layers (Chandraul and Singh, 2013):

- MAD-Data Acquisition Layer (MDAL)
- MAD-Data Processing Layer (MDPL)
- MAD-Data Storage Service Layer (MDSSL)

b) Cloud Agro System: It is a cloud computing based system designed to monitor the overall information related to agricultural activities. Up to date IT tools provide online language translation mechanisms in order to overcome language and tradition limitations in worldwide agricultural community. As a result, any type of information stored on the cloud is presented to the user's language of choice, supporting any decisions related to crops production. Furthermore, through sophisticated features, such as online questionnaires, researchers can exploit the experience of farmers worldwide in the development of new agricultural tools and techniques (Patel and Patel, 2013).

c) Agricultural mobile cloud-based platform: It is a concept model of Mobile Cloud Computing (MCC) technology which assists farmers to achieve relatively better cultivation and marketing by using simple handheld devices such as laptops, tablets and smartphones which support 2.5G, 3G or 4G technologies. In this application a mobile server is established including Application Service Providers (ASP) which offer to farmers on-demand software services via a network architecture. The developer is connected to the ASP and users are connected to the mobile infrastructure providing application features and services which are designed to be user friendly (Prasad, 2013).

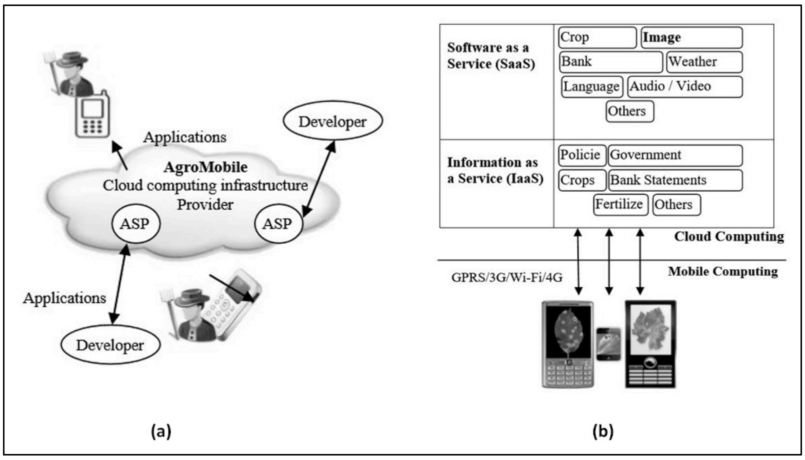

Fig. 3. Mobile Cloud Computing a) System Model and b) Proposed Services

d) WSAN linked to agricultural cloud computing system: This approach integrates Wireless Sensor Actor Networks (WSANs) with cloud computing services to assist farmers optimize the usage of available resources in agricultural production. Environmental data from the fields are acquired by the sensors and process with the help of a decision support unit for actuating the process. Sensor nodes which acquire environmental data and a group of actor nodes which operate according to the decision taken by the decision support system are interconnected with wireless medium. The layered architecture shown in Fig. 4 consists of three groups: sensing group, cloud service group and actuator group (Mahesh et al., 2014).

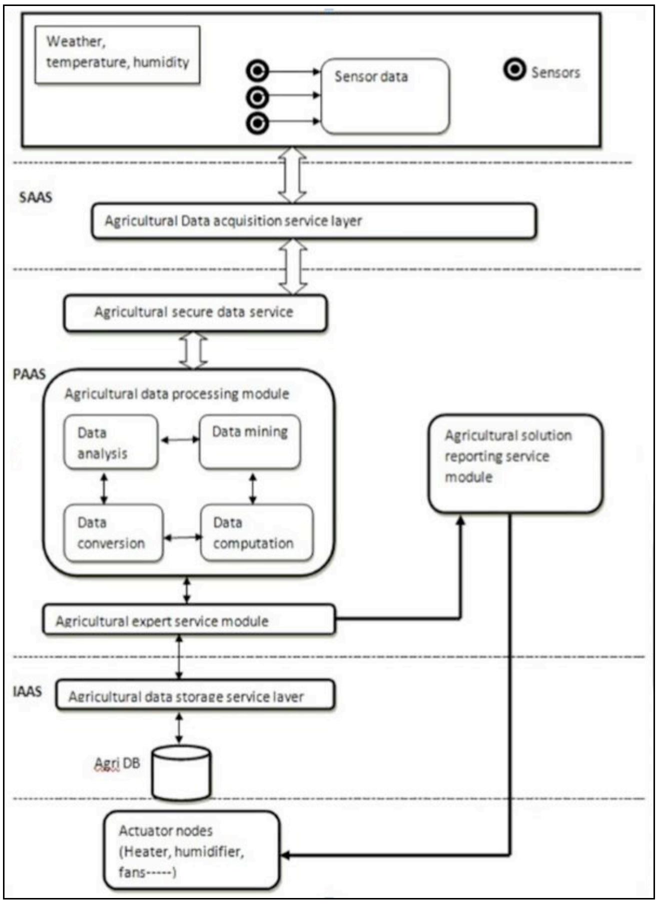

Fig. 4. Agricultural WSAN Cloud

e) PDCA cycle based agricultural cloud services: According to this perspective the process of agriculture production is regarded as a PDCA (Plan-Do-Check-Act) cycle as shown in Fig 5. Based on this process, primary sensing and knowledge management techniques are principally used to provide cloud services. Production data related to weather and soil, crop images, farming observations and cultivated plots of land are routinely collected. In addition analysis engines, such as data miners, are employed for analyzing the stored data and provide advice as well as suggestions concerning the agricultural production (Hori et al., 2010).

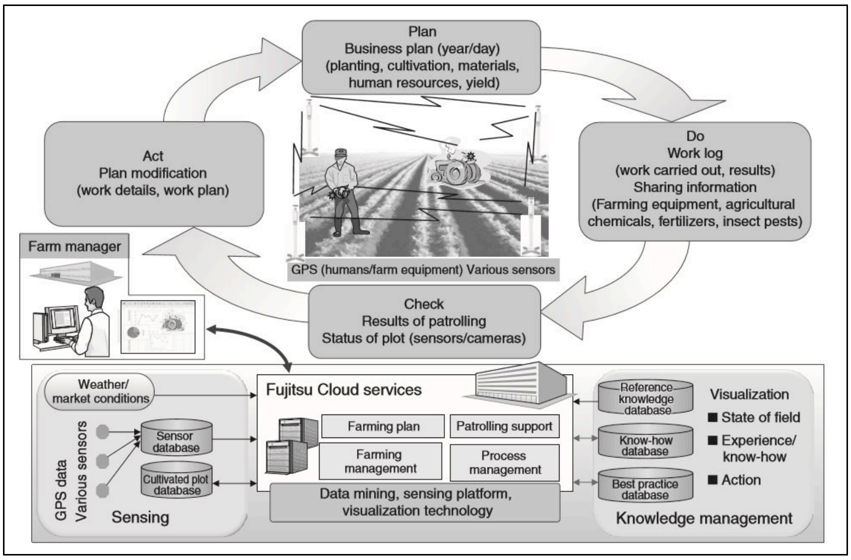

Fig. 5. PDCA Cycle and Cloud Services in Agriculture

3.3 Benefits and Challenges of Cloud Computing in Agriculture

Agriculture, and especially climate-smart agriculture, is a field which is highly benefited with the applications of cloud computing with regard to resources sharing, cost saving and efficient agro systems construction. Moreover, the integration of agricultural processes with cloud computing has given a significant impetus to production, marketing and sales of agricultural goods. In particular, cloud computing technology in agriculture presents the following advantages (Prasad et al., 2010; Gao et al., 2011):

- Data management is performed by the service provider guarantying better and efficiently organized information resources.
- Stakeholders can access information at any time or location from the e-data bank databases.
- Communication and interaction among users worldwide is expeditive, effortless and of sufficient security.
- Maintenance infrastructure requirements are drastically reduced as service providers are responsible for all technical issues.
- Security is enhanced as all data and resources are stored in the cloud and maintained centrally by the service providers.
- Farmers and researchers are motivated to get more involved into the field of climate-smart agriculture as all communication attempts are result oriented.

- The problem of rural-urban migration can be reduced as cloud computing services are provided remotely at any time. This will aspect might also aid in unemployment control.
- Due to the mass involvement of different stakeholders, the implementation of cloud computing technology in agriculture might boost sustainable growth and economic development.

Despite the overall growth of the agricultural sector due to the employment of cloud computing, certain concerns are beholden as well.

One of the main concerns is related to security and privacy, as sensitive data are delivered to a third party and might be compromised by eventual hacking attacks due to deficient maintenance and supervision of the security systems. This problem might be solved through the careful selection of reputed and reliable cloud service providers (Ashktorab and Taghizadeh, 2012).

Another constraint of major importance is linked to the requirements of cloud computing services in constant and high-speed network connectivity. In order for farmers to take advantage of cloud computing technology benefits it is essential to ensure better and low-cost network coverage in distant rural areas (Dalvi and Kumbhar 2014).

A final constraint regarding the use of cloud computing in the field of agriculture is the extent of computer illiteracy in rural areas as most farmers are not able to understand the functions of software and internet or complete tasks and solve problems on a computer without assistance. Hence, training centers should be established in order to offer guidance regarding computer skills and cloud computing services usage (Dalvi and Kumbhar 2014).

4 Conclusions

Cloud computing finds application in almost every field of production and services. Agriculture is one of the fields which could be highly benefitted from the features offered by this innovative technology. Cloud computing provides modern agriculture equipment, weather observation and forecasting, agriculture planting and breeding technology, as well as production organization and management methods. Furthermore, it interconnects the farmers, being able to exchange knowledge and experience through communication and information sharing. Modernization of agriculture by communicating rapidly the knowledge about new techniques improves the utilization of natural resources, reduces climate dependency, assists in environment and ecosystem protection and promotes sustainable development. Therefore, the future growth of agriculture is depended on the adaptation of new technologies with a focus on farmer needs such as cloud computing. The use of appropriate technologies aids the agricultural community in terms of accessibility and affordability. Cloud computing in climate-smart agriculture provides a convenient environment for services and innovations in a flexible regulatory environment.

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