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MODELING AND SIMULATION OF CLOUD COMPUTING SOLUTION FOR DISTRIBUTED SPACE DATA STORAGE AND ACCESS IN MOBILE COMMUNICATION NETWORKS

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Storage and retrieval of space signals require an advanced set of core technologies that can be implemented with a cloud computing paradigm. In this work we propose a cloud computing solution for the distributed space data storage and access in mobile communication networks. The modeling and simulation results show that the proposed solution performs satisfactorily in the space data processing. In the future, experimental verification of the cloud computing model and its implementation are envisaged.

Keywords: *Space signal storage, cloud computing system, mobile network, simulation, distributed system.*

1. INTRODUCTION

The high-bandwidth radio telescopes are generating massive bodies of digitized data. The main challenges are therefore to store and access the recorded data with the highest efficiency. The latest developments in ubiquitous technologies have resulted in smart phones and tablets as the future computing and service access devices. It is just the devices that have led to increased mobility of scientists who are now able to work not only in the laboratories but anywhere in the world. The main problem is how to gain access to huge amounts of data and processing power when working with mobile devices. On the other hand, we have another problem – that of how to store this data so it could be accessed using distributed approach in mobile networks. The solution can be found in the cloud computing (CC) paradigm where the access to the space data and computational intensive applications can be offered as a service. According to Juniper Research, annual revenues from cloud-based mobile applications will reach nearly $9.5 billion by 2014, fuelled by the need for converged, collaborative services, the widespread adoption of mobile broadband services and the deployment of key technological enablers [1]. The existing CC systems should be extended to support distributed algorithms for storage of real-time acquisition data, with synchronization of different data streams, data security, data consistency and system's scalability in mind. One of the solutions is presented in our research. In recent years, there was massive growth in the application markets (Google Play, Apple App Store, Windows Phone Store, Amazon Appstore, etc.) targeted at mobile devices which now have more than 2 billion applications in various categories such as entertainment, education, business, news, games, social networking, etc. Gartner is forecasting that worldwide shipments are expected to reach 197 million units this year. For comparison's sake, tablet shipments totaled 116 million units in 2012. By 2017, tablets will out-ship desktop and notebook PCs by a huge margin. The research firm expects tablet shipments to reach 467.9 million units versus 271.6 million units for PCs. Of the 1.875 billion mobile phones to be sold in 2013, 1 billion units will be smartphones, compared with 675 million units in 2012 [2]. Such fast growth of the mobile devices also has high impact on the way scientists perform their research. They become more mobile, they can work from anywhere in the world. This high level mobility demands services to make laboratory equipment and data to be available in their mobile devices. As mobile devices usually have restrictions in terms of computational power and energy consumption, many of the computing-intensive tasks can be offloaded to remote resource providers in the cloud, and the results can be transferred to the client. The concept of offloading data and computation in CC is used to address the inherent problems in mobile computing by using resource providers other than the mobile device itself to host the execution of mobile applications. Such an infrastructure where data storage and processing could happen outside the mobile device could be termed a "mobile cloud" [3].

The aim of this work is to model and simulate the created mobile cloud computing solution for distributed space data storage and access in mobile networks.

2. RELATED WORKS

During the last years there was a huge interest in mobile and cloud computing research. The researchers focus on CC architectures, internet access in mobile devices, routing protocols, etc.

Fernando *et al*. [3] have made an extensive survey of current mobile CC research and presented different definitions of mobile CC in the literature. One of the few examples of the cloud storage architectures can be found in the work by K. Liu and L. Dong [4]. They present the cloud storage architecture based on eyeOS web operating system. Experimental results have verified the proposed system and shown acceptable performance. Another solution of the cloud-oriented file service for mobile Internet devices is reported by H. Mao *et al*. [5]. These authors present a cloud-oriented file service Wukong, which provides a user-friendly and highly available facilitative data access method for mobile devices in cloud settings. It supports mobile applications which may access local files only, transparently accessing cloud services with a relatively high performance. The method offers heterogeneous cloud services for mobile devices by using the storage abstraction layer. H. Mao *et al* have implemented a prototype with several plugs-in and evaluated it in a systematic way [5].

There are some works concerning security aspects in cloud storage domain. One of the extensive reviews has been made by A. N. Khan *et al*. [6] An interesting approach was presented by M. E. Frincu [7]. This author proposes to build highly available applications (i.e., systems with low downtimes) by taking advantage of the component-based architecture and of the application scaling property. In this work, solution is presented for the problem of finding the optimal number of component types needed on nodes so that every type is present on every allocated node. The solution relies on genetic algorithms to achieve the set goals [7]. One of the first tries to combine the CC paradigm and radio telescopes was made by Drungilas *et al*. [8]. The authors introduce a distributed remote control framework for radio telescopes using the CC principles.

As the literature analysis has shown, there are no research works on mobile cloud solutions for storing and retrieving high amount of space signal data in mobile environment, as this environment has specific requirements and proposed solutions are not suitable.

3. CLOUD COMPUTING ARCHITECTURE FOR DISTRIBUTED SPACE DATA STORAGE AND ACCESS

Cloud computing has resulted in introducing new kind of information & services and new ways of communication & collaboration. Cloud contains online social networks in which scientists share data and analysis tools to build research communities [9]. The CC can be defined as the aggregation of computing as a utility and software as a service where the applications are delivered as services over the Internet, the hardware and systems' software at the data center provide these services [10]. The concept behind the CC is to offload computation to remote resource providers. The key strengths of CC can be described in terms of the services offered by cloud service providers: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) [3]. An abstract level layered CC architecture can be seen in Fig. 1.

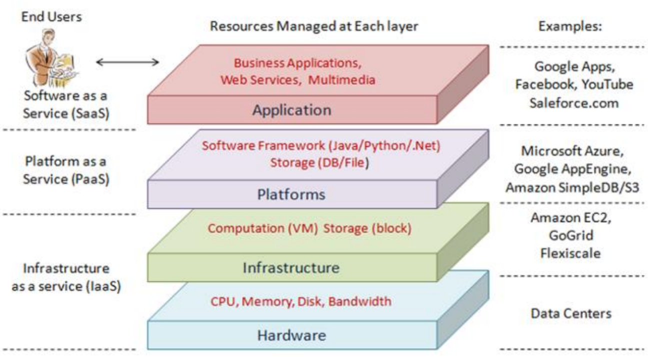

Fig. 1. Layered cloud computing architecture [9].

The CC architecture for distributed space data storage and access has specific requirements, as it consists of unique hardware and software combination which have to be offered as a service. In our proposed model (Fig. 2) in the IaaS layer there are provided high-speed space data capture from radio telescope and digitizing of captured data, space data pre-processing and signal storage in NI RF Record and Playback System, and space data exchange with cloud. In the PaaS layer provided are: the data storage in relevant servers (using distributed database Citadel), and the data and computing power exchange with local area network and remote users. In the SaaS layer the data exchange with signal processing service is provided in which high computing power requiring computations can be offloaded from LAN users, remote users and especially mobile cloud users.

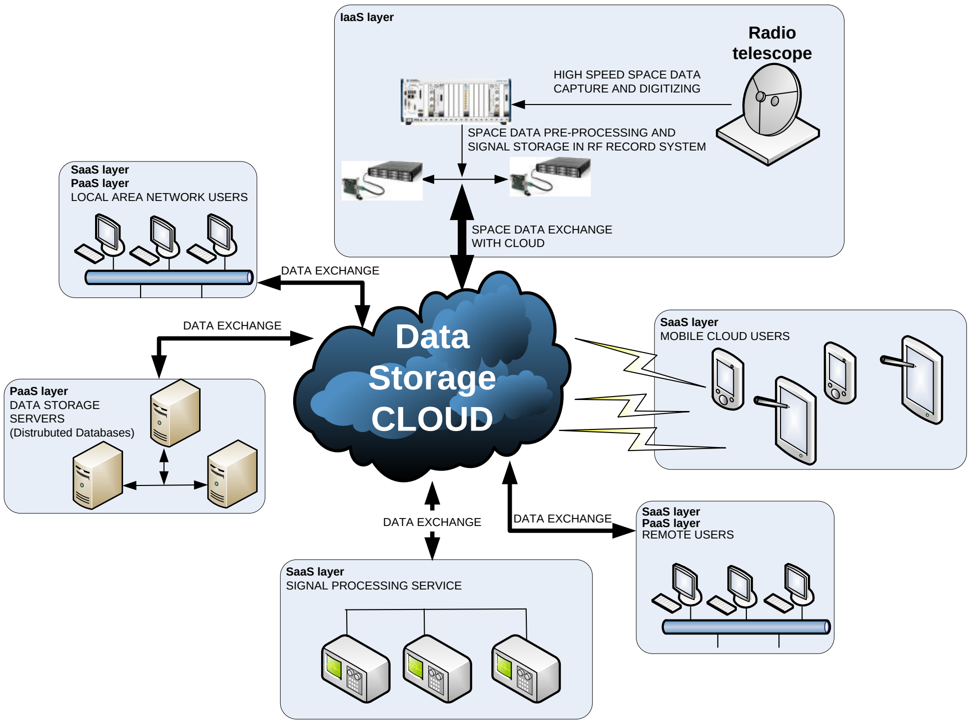

Fig. 2. A high-level diagram of the proposed solution for distributed space data storage and access in mobile communication networks.

4. DEVELOPMENT OF THE ALGORITHM AND PROGRAM FOR DISTRIBUTED SPACE DATA ACCESS IN MOBILE CLOUD

We have designed an algorithm (Fig. 3) for the space data or service access in the mobile communication networks. When the user wants to access the data in the cloud the first step is authentication process which must be passed to grant the access. If it fails, the user is rejected and cannot use the data or services. If the access is granted, the user's request is checked. If user wants to access data from Citadel database, this is added to the DB server queue, and, when the server has available resources, the database query is formed and the requested data trace is retrieved to user through mobile network. Similar situation is when the user wants to use some computational services from the cloud. The first server adds it to the queue, and then the requested services are to be provided. After these steps, the algorithm checks if the user has more requests and if no connection is terminated; if the user has requests, the process is repeated.

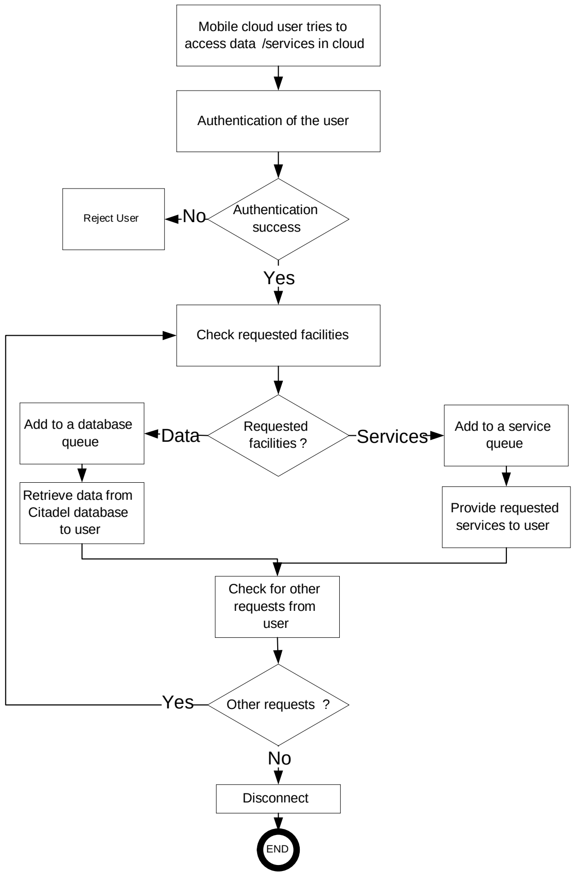

Fig. 3. Flowchart of distributed space data access in mobile cloud

5. METHODOLOGY AND EXPERIMENTAL MODEL

The experiments were carried out in the simulation environment ESTINET 8.0 [12], which was installed in Fedora 14 Linux operating system. The environment was chosen as using the existent Linux TCP/UDP/IP protocol stack providing high-accuracy results; it can be used with any actual Unix application on a simulated node without additional modifications; the environment supports 802.11a/b/g, 4G LTE communication networks and mobility modeling of the nodes, offering a user-friendly user interface and being capable of repeating the simulation results.

In experimental scenario 1 (Fig. 4), the network model is created where the space data from the server running Citadel dababase is retrieved to use the LabVIEW DSC module and is provided to the 4G LTE mobile nodes. The modeled 4G LTE network consists of four type nodes: Packet Data Network gateway (PDN GW); serving gateway/Mobility Management Entity (SGW/MME); eNodeB; and User Equipment. In experimental scenario 2, where the same data was transferred to mobile nodes, the connection is provided by the 802.11g protocol.

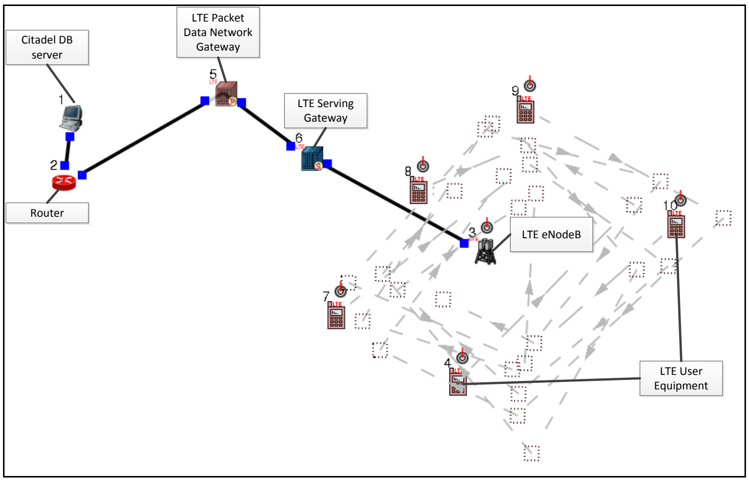

Fig. 4. 4G LTE simulation scenario.

The structural requirements for ESTINET 8.0 simulation model were analyzed (the parameters are shown in Table 1). The experiment was carried out for the number of nodes in the network from 1 to 10, with simulation of different traffic congestions in order to determine the influence of the node number on the data transfer efficiency. The receiver's nodes are moving at a speed of 10 m/s using a random waypoint mobility model.

Table 1

Parameters for experimental scenarios

	Parameter	**Value**
	Simulation time (s)	60
	Mobility model	Random Waypoint
	Path Loss Model	Two Ray Ground
	Average velocity of nodes (m/s)	10
LTE eNodeB (Scenario 1)	Frequency (MHz)	2300
	Transmission Power (dbm)	43
	Bandwidth (MHz)	10
	Receive Sensitivity (dbm)	-96
	Antenna Height (m)	50
	Ricean Factor K (db)	10.0
802.11a (Scenario 2)	Channel Number	36
	Frequency (MHz)	5180
	Transmission Power (dbm)	16.02
	Receiving Sensivity (dbm)	-82.0
	Antenna Height (m)	1.5

6. RESULTS AND DISCUSSION

Using the created simulation models a number of experiments have been run. To estimation were subject: the data transmission efficiency (incoming/ outgoing throughput in the LTE eNodeB); packet drops and collisions with a different number of user equipment nodes in the network. The data was transmitted using the TCP protocol and a 1000-byte packet. The simulation took 60 s (Table 1).

The analyzed results show the throughput in the LTE eNodeB with a different number of nodes (clients) (Fig. 5). At the use of one node the throughput was stable with the average of 0.089 MB/s. With 5 and 10 nodes the throughput was fluctuating with the average of 0.094 MB/s and 0.092, respectively.

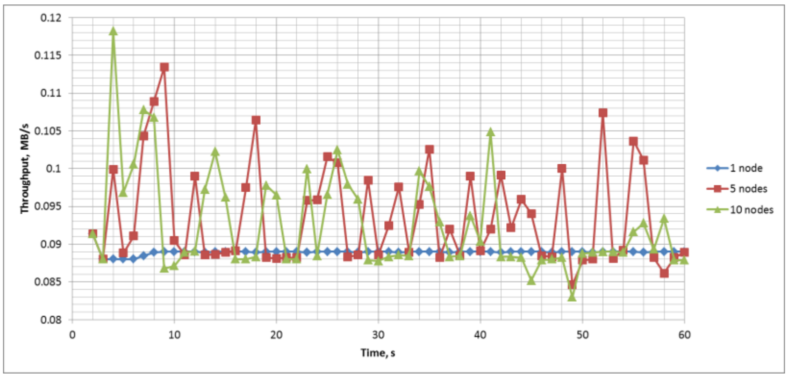

Fig. 5. Throughput in the LTE eNodeB with different number of clients (nodes).

Similar analysis was made for the input throughput in the LTE eNodeB with a different number of clients (Fig. 6). The results are close to those for the output throughput. With one node the average throughput was 2,544 MB/s, with 5 nodes – 2.56 MB/s, and with 10 nodes – 2.56 MB/s. It can be seen that at a small number of user equipment nodes in the network the changes do not have significant influence on the throughput.

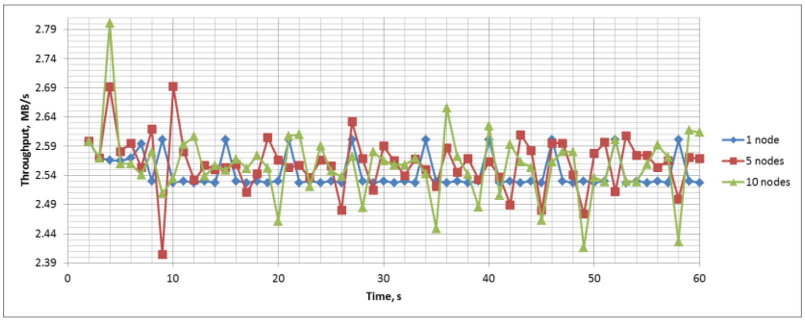

Fig. 6. Throughput in the LTE eNodeB with different number of clients (nodes).

Another situation is when the 802.11a standard is used for communication (Fig. 7). Here we can see a significant influence on the throughput in the mobile node's input with a different number of nodes. The highest throughput is achieved with a single node. As the number of nodes increases the throughput decreases.

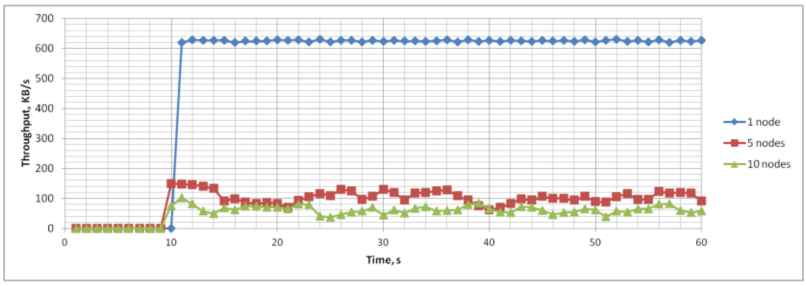

Fig. 7. Throughput in the 802.11a mobile node with different number of clients (nodes)

7. CONCLUSIONS

The created cloud computing solution for the distributed space data storage and access in mobile communication networks allows for access of the space signal in the desired location at the right time. The layered architecture with an infrastructure-as-a-service (IaaS) layer of the proposed model has shown to provide a high-speed space data capture, space data pre-processing and signal storage, while the platform-as-a-service (PaaS) layer stores the data in relevant servers, and the software-as-a-service (SaaS) layer exchanges the data with signal processing service. The simulation results have shown that this solution performs satisfactorily and can be implemented in the space data processing.

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MĀKOŅSKAITĻOŠANAS RISINĀJUMA MODELĒŠANA UN SIMULĀCIJA IZKLIEDĒTAI KOSMISKAS IZCELSMES DATU GLABĀŠANAI UN PIEKĻUVEI MOBILOS KOMUNIKĀCIJU TĪKLOS

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Kopsavilkums

Kosmiskas izcelsmes signālu uzglabāšanai un atjaunošanai nepieciešams moderns tehnoloģisks risinājums, kurš var tikt izveidots, izmantojot mākoņskaitļošanas platformu. Šajā rakstā tiek izklāstīts minētajam uzdevumam izstrādāts mākoņskaitļošanas risinājums izkliedētai kosmiskas izcelsmes datu glabāšanai un piekļuvei mobilajos komunikāciju tīklos. Literatūras pārskatā konstatēts, ka pašreiz kosmiskas izcelsmes signālu glabāšanai un atjaunošanai mākoņskaitļošana tiek pielietota ļoti reti. Izveidotajam modelim tika veikta simulācija, un tās rezultāti apstiprina, ka kosmiskas izcelsmes datu apstrādē izstrādātais risinājums nodrošina apmierinošu veiktspēju.

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