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Cloudlet Selection Strategy According to the Types of Applications in Cloud Networks

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***Abstract*— The selection of the most suitable cloudlet that allows running users applications rapidly in the cloud is still an urgent problem. For the elimination of resource shortages, power consumption, and delays in communication channels on mobile devices, the remote cloud servers are placed adjacent to devices. The delays on communication channels and power consumption on mobile devices are reduced through cloud-based mobile computing. In the paper we propose a strategy for selecting a cloudlet with high computing productivity, which provides a fast solution, considering the complexity degree of the application (file type). Also, in the paper, the solution of the task in a cloudlet close to the user, the downloading of the task to the cloudlet, the sending of the outcome to the user, and the minimization of network interruptions are presented.**

***Keywords*— Mobile cloud computing, Cloudlet, Power consumption, Communication channel, File types, Network delays**

I. Introduction

Although widely used traditional (centralized) cloud computing offer high-performance and storage, processed data cannot be delivered to users at high speeds due to network delays. Recently mobile users have become numerous, and therefore, due to remote delivery of cloud servers and the Internet overload, there occur delays in sending processed data to the user. For solving these problems (resource scarcity, power consumption and delays in communication channels, etc.) cloud computing resources should be placed close to the user. Thus, the creation of cloudlet-based mobile cloud computing is an actual issue for solving these problems.

II. Problems and aim of the Proposed Work

The computer devices used to create cloudlet networks has various technical capacities. In traditional cloudlet-based mobile computing networks, the user application is routed and executed by the Resource Management Center (RMC) to any cloud with free resources. The type of application software (degree of complexity) and the selection of the appropriate cloudlet are not analyzed. Also, the issue of proximity between users and cloudlets is not considered here. Additionally, if the applications in a cloudlet are not optimally distributed in a balanced way (some cloudlets are fully loaded, some are empty), their execution time is extended, mobile device's power consumption increases. Thus, the noted problems increase the mobile devices' power consumption and network delays. For solving these problems, the applications with a high degree of complexity should be solved in a cloud with high technical capabilities. If applications with high-complexity are solved in cloudlets with high technical capabilities, then the problem-solving time will be less. Firstly, the type (level of complexity) of the user application is determined. According to the type of application, we select the appropriate cloudlet with the highest technical capabilities, close to the user from the appropriate cloudlets. The proposed strategy reduces the power consumption of mobile devices and the implementation delays of the application by loading them to the appropriate cloudlets. Reduction of energy consumption of mobile devices.

- Selection of cloudlets according to the type of application.
- Decreasing of network delays.

III. Related Works

The article [1] examines the problems that occurred in loading and solving the applications in the cloud. The migration of applications in mobile cloud computing on cloud servers has been examined [2]. In [3], the delays in delivering results to users when using remote cloud servers have been analyzed. Here, the usage of cloudlets has been proposed to eliminate delays. The paper [4] discusses the issue of choosing the nearest cloudlet serving to the mobile device from a large number of cloudlets. Since cloudlets can serve a limited number of users and are located closer to the mobile device, so they provide better security issues compared to distant clouds [5]. In paper [6], the usage of cloudlets to reduce power consumption in mobile devices and minimize network delays have been investigated. In [7], the issue such as balanced distribution of resources in the cloud network considering the mobility of users has been studied and proposed two heuristic algorithms to solve the problem. A planning scheme has been proposed to ensure the optimal distribution of workload in the cloud environment considering the requirements of QoS-services [8]. The paper [9] shows that better QoS services are provided to users due to network delays when solving the applications in the cloud. The paper [10] discusses how to solve the problems on virtual machines located near mobile devices by using new Mobile Edge Computing (MEC) technologies. In several studies [11] have suggested creating cloudlets by mobile users near base stations, as well as methods for the efficient usage of cloudlet resources. Also, the execution time of tasks on the created virtual machines was analyzed. In some studies, an algorithm has been proposed for selecting the cloudlet providing the optimal distribution of the loaded issues between the cloudlets and the solution of the problems in a short period of time [12].

IV. The architecture of Cloudlet-Based Mobile Cloud Computing

For efficient use of cloudlets resources, hierarchically structured cloudlet-based mobile cloud computing is offered using Resource Control Center are proposed (Figure 1).

Cloud computing servers are on the first level, and the cloudlets are on the second level, close to the base stations. The third level includes mobile devices. There exists information about the location of cloudlets in the RCC and the technical capabilities of a hierarchically structured network. RCC has to keep all existing cloudlets in the cloudlet network and mobile users' data identifiers (IDs) in a table form and to direct applications to cloudlets based on user request. Mobile user's package program is downloaded from remote cloud servers to the RCC of the cloudlet network. The control server in the RCC determines in which cloudlet to resolve the tasks of mobile user based on server table. The central server also provides data exchange between cloudlets or between the user and the cloudlet. The control center contains information about the computer devices applied for cloudlet creation. The control center also collects information about the technical capabilities of cloudlets and the location of users close to the cloud in the mobile network. Therefore, according to the incoming request, the application called from the cloud servers is placed in the cloudlet that provides the user's requirements. Mobile Internet users download and use applications to the nearest cloudlets, and this frees the network from downloads on its turn. This architecture provides the solution to some of these tasks (resolution time of task, power consumption, communication channel interruption). Thus, cloudlets are created close to the base stations of mobile operators for users effectively to use the services of mobile cloud technologies. Advantages of cloudlets usage include rapid service admittance, mobility support, reduction of roaming expenses. Let observe the energy savings of mobile devices and minimizing network interruptions when solving tasks in the cloud.

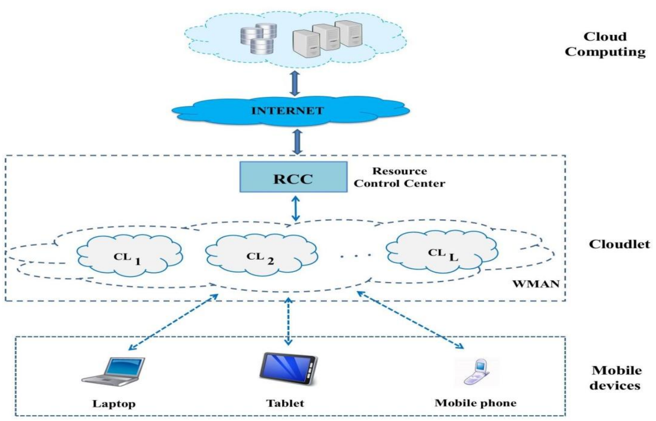

Fig. 1. The architecture of Cloudlet-based mobile cloud computing

V. The cloudlets Selection Method According to the Types of Applications

The paper deals with the placement of Wireless Metropolitan Area Networks adjacent to base stations and the efficient usage of cloudlets resources near the user. Considering WMANs volume, incorrect placement of user tasks in cloudlets and inappropriate load supply between them (some cloudlets are burdened, some unused) can lead to prolongation of processing period and interruptions in ensuring results to user. For overcoming this shortcoming, the placement of cloud computing resources near the user is necessary. In this case, cloudlets handle the requests rapidly, enabling the less power usage by mobile devices.

If computing and memory resources of cloudlets cannot process its mobile users' requests, he/she must choose another cloudlet adjacent to it, taking advantage of those resources. Task solution time, as well as its delivery period to the user are subject to the computing power of the virtual machine installed in cloudlets, including to the number of base stations (nodes) between the cloudlet and the user. The smaller the number of nodes between the cloudlet and the user, so the fewer the delays. It provides delivery of results and information rapidly. Prior to selection of the cloud, the network is analyzed and the status is determined. Consequently, once it has been analyzed, the data about the cloudlets' loading and technical capabilities, and the date of request is received, it can be determined in which cloudlet the task will be solved rapidly. Also, the number of communication channels being small increases the reliability of security tasks.

RCC evaluate the potential cloudlets when solving the task of deploying the application software on any cloudlet. Some criteria (high technical capabilities, availability of free resources, the minimum number of communication channels, the distance between the user and the mobile base station, etc.) should be considered when selecting the cloudlet while the assessment.

The selection of the most suitable application from the majority of cloudlets and its loading is still a great problem. The strategy for selecting a cloudlet that provides rapid processing of the user application from a large number of cloudlets with different technical capabilities has been proposed in the paper. The resolution time of user applications in cloudlets with different technical capabilities also differs. Therefore, we recommend selecting the most suitable cloudlet among the numerous cloudlets available close to the mobile device according to the type of application used by the user. Using the proposed strategy, we provide the reduction of energy consumption of mobile devices by ensuring rapid implementation of programs. Also, we can balance the system loading by ensuring the correct distribution of applications between cloudlets. As a result, we eliminate the solution task of applications in a cloud by load balancing.

There can be more than one cloudlet close to the mobile users, but most users can use the same cloudlet based on a certain criterion (proximity). Thus, some cloudlets that are close to the user are loaded more, while other cloudlets remain empty. The purpose of cloudlets usage is to reduce delays and energy consumption. However, if a cloudlet is overloaded, then the resolution time of the solved task will prolong and the delay will increase. For this reason, the quality of service (QoS) is low. The balanced distribution of loads is required to overcome such a situation. Our aim is to propose a strategy balancing the load of the system, energy consumption and reduce delays. This task can be solved if the applications are distributed in a balanced form between several cloudlets instead of running the applications in a single cloudlet. If a user (mobile device) has several cloudlets with different technical capabilities, the selection of a cloudlet allowing rapid processing of the user application is necessary. Thus, the accurate selection of cloudlets according to the type of applications used by users reduces the above-mentioned problems. Depending on the type of utilised application, the cloudlet selection method, which solves it rapidly from a large number of cloudlets, reduces power consumption on mobile devices, delays in the network and ensures a balanced distribution of network load between cloudlets. For instance, the types of applications to be used (downloaded) can be grouped as follows [24]:

- an applications group requiring big and storage resources (algebra, numerical, etc.),
- an applications group requiring medium computational and storage resources (game, Web service, etc.),
- a group of applications that require low computational and memory resources (file creation, sorting, etc.).

Cloudlet-based mobile computing network includes L number of cloudlets based on non-homogeneous computers (servers, desktops, notebooks, etc.). Information on the technical competences of computing devices utilized for cloudlets installation is placed in RCC in the form of a table. The set of cloudlets is also grouped according to the number of groups of utilized applications. In our task, we divide cloudlets into three groups. The computer devices included in the C1 cloudlet set has high technical capabilities. The computer devices included in the C2 cloudlet set has medium technical capabilities. The computer device included in the C3 cloudlet set has low technical capabilities.

Thus, we group users' application software according to the level of complexity and cloudlets according to their technical capabilities. Based on the user request, the RCC selects the cloud according to the type of application. The comparison of the resolution time of the task was investigated considering the level of complexity of mobile users' applications, placing them in appropriate cloudlets. The experiment was conducted on cloudlets created in the AzScienceNet computer-science network of the Azerbaijan National Academy of Sciences. For the experiment (L1, L2, L3) the following three computer devices with the technical capabilities given below were used in the creation of cloudlets:

- Cloudlet L1: Intel Xeon E5 - 2650, 2.3 Ghs, core-16, RAM - 32 GB, HDD - 1Tb.
- Cloudlet L2: Lenovo Y50, Intel Core i7, 2.5 Ghs, core-4, RAM - 8 GB, HDD: 500 GB.
- Cloudlet L3: ASUS Zenbook, Intel Core i5, 1.6 Ghs, core-2, RAM - 8 GB, HDD – 300 GB.

As the experiments were conducted within the corporate network, the uploading of the task to the cloudlets, obtaining the results and delays in the network were considered. Also, in the experiment, the resolution of tasks included in the group of applications with a high degree of complexity was considered. For carrying an experiment, the multiplication of matrices in a size 10000x10000 was analysed using MATLAB R2020b package software.

The correct selection of cloudlets according to the complexity degree of the user application software to reduce the resolution time of the task has been experimentally determined. The experimental results are shown in Table 1.

As seen from the table, when the task of matrices multiplication is solved in the cloud L1, the solution time will be less about 3.92 times than in L2, and this will reduce the power consumption of the mobile device in standby mode. If we increase the size of the matrix, this number will increase many times. Thus, as seen from the experiment, the placement of users' tasks in the cloudlet network creates problems in its solution time. Computers with high computing performance solve the tasks rapidly. Therefore, users' tasks should be referred by RCC to a cloud with high technical capabilities according to their complexity level (format) so that the tasks can be solved rapidly. The sooner the issue is resolved, the lower the power consumption of the mobile device in standby mode.

TABLE I. SOLUTION TIME OF THE TASKS IN DIFFERENT CLOUDLETS

Cloudlet	Prosessor	Core	RAM	HDD	Operating system	Multiplication time of matrices in a size of 10000 × 10000 (seconds)
L1	Intel Xeon E5 – 2650, 2.3 Ghz	16	16 GB	1000 GB	Windows 10 × 64 bit	4.8595
L2	Intel Core i7, 2.5 Ghz	4	8 GB	500 GB	Windows 10 × 64 bit	11.0634
L3	Intel Core i5, 3.1 Ghz	2	4 GB	300 GB	Windows 10 × 64 bit	19.0436

If there don't exist empty virtual machines in the cloudlet C1, then the task is directed to the cloudlet set C2. Generally, if the cloudlets sets do not have empty resources, the solution is saved in standby mode by RCC. As soon as there appeared empty resources in the suitable cloudlet set, the task is directed to it. Thus, the selection of the appropriate cloudlet in solving the user's task reduces time, energy consumption, and delays. Considering the mentioned above, a mathematical model will be proposed in future research to provide energy consumption on mobile devices, the loading of the task into the cloud, the obtaining of the results, the reducing of the network delays, and balanced distribution of loads in the cloudlets.

CONCLUSION

In the paper, the strategy for the selection of cloudlets according to the complexity level of user applications has been proposed. The computer devices used to create the Cloudlet network has various technical capabilities. A model has been proposed for the solution of high-complexity applications in a cloudlet with high technical capabilities under certain conditions. Firstly, we determine the type of user application. According to the type of application, the most appropriate cloudlet with high technical capabilities and close to the user is selected from the corresponding cloudlets. Using the proposed strategy, we can reduce the power consumption and delays of mobile devices by downloading applications to the appropriate cloudlets, and simultaneously, prevent the loading of multiple users' tasks on any cloudlet close to them. Thus, the experimentally proposed method can be used to reduce energy consumption in mobile devices.

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