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FOG COMPUTING TECHNOLOGY IN DISTRIBUTED SYSTEMS

Abstract. Topicality. The concept of fog computing is an evolutionary stage in the development of the cloud concept. It occupies a leading position among the general trends in the development of information technology. The emergence of this concept is closely related to the origin and development of the concept of the Internet of Things. **The results.** The subject area was analyzed. It includes an analysis of current trends in the field of organizing distributed computing, an analysis of the use of population algorithms and ontology models for solving optimization problems in distributed systems, an analysis of models, methods and algorithms for solving the problem of transferring the computational load in distributed systems implemented on the basis of fog computing. **Conclusion.** It has been revealed that the concept of fog computing makes it possible to solve most of the problems associated with the load on the communication infrastructure and the latency of information exchange. But they do not resolve issues related to the high dynamism of the foggy environment and the concomitant decrease in the efficiency of the distributed system.

Keywords: computer system, distributed system, fog computing, cloud computing, Internet of Things.

Introduction

Currently, the new paradigm of fog computing, which can be considered as an extension of the cloud concept, has found wide application in many fields. This is due to the fact that today clouds do not meet the high requirements of mobility, low latency and local awareness [1, 2]. A promising solution in this case seems to be a selective shift of computing, communication, control and decision making to the places where data is generated, which corresponds to the basic principles of the concept of fog computing [3, 4].

The concept of fog computing is an evolutionary stage in the development of the cloud concept. It occupies a leading position among the general trends in the development of information technology. The emergence of this concept is closely related to the origin and development of the concept of the “Internet of Things” (IoT) [5, 6]. Scenarios for using the concept of fog computing are very diverse. They are determined by the development of related technologies. This concept has been successfully used in the creation of systems such as smart home, smart transport, e-health, e-government, trade and financial services, industrial production, technological and business process management, and much more [7–12].

The definition of “fog computing” was first introduced by Cisco in 2011.

ШщЕ and is currently actively developing due to the following factors:

– the computing power of communication equipment and devices located in the fog layer allows for additional calculations;

– the number of end devices is growing very quickly, and this trend will continue in the foreseeable future.

– it is advisable to relieve the data processing center (including cloud ones) from performing complex computing processes [13, 14].

Fog computing is a tiered model that provides ubiquitous access to a shared pool of scalable computing resources. Fog computing minimizes the network response time of supported applications and also provides end devices with local computing resources and, if necessary, network connectivity to centralized services” [15]. The fog computing architecture can be considered as a “layer” between the cloud and end (user) devices (Fig. 1).

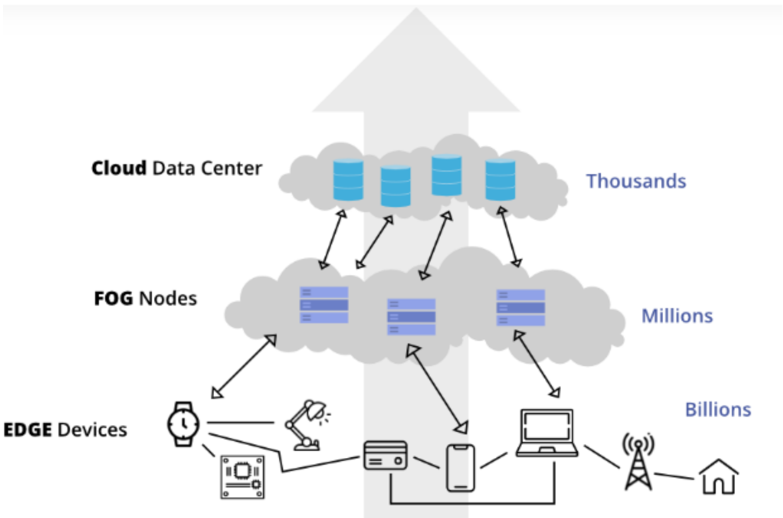

Fig. 1. Fog computing concept

The fog computing environment consists of network components such as routers, switching devices, TV converters, proxy servers, base stations, sensors, etc.

The key difference between the fog concept and the cloud concept is the ability to dynamically transfer the computing load from the cloud to the periphery of the network infrastructure using fog layer devices, as well as partial placement of the load in the fog layer.

This allows you to significantly reduce the load on the communication infrastructure of the network [16].

The purpose of the article is to determine the features of fog computing in distributed systems

Research results

The main problems associated with the organization of the Internet of Things concept and the use of fog computing technology to solve them are shown in Fig. 2.

Major cloud providers: Amazon, Google and Microsoft are developing the concept of fog computing based "serverless architecture"

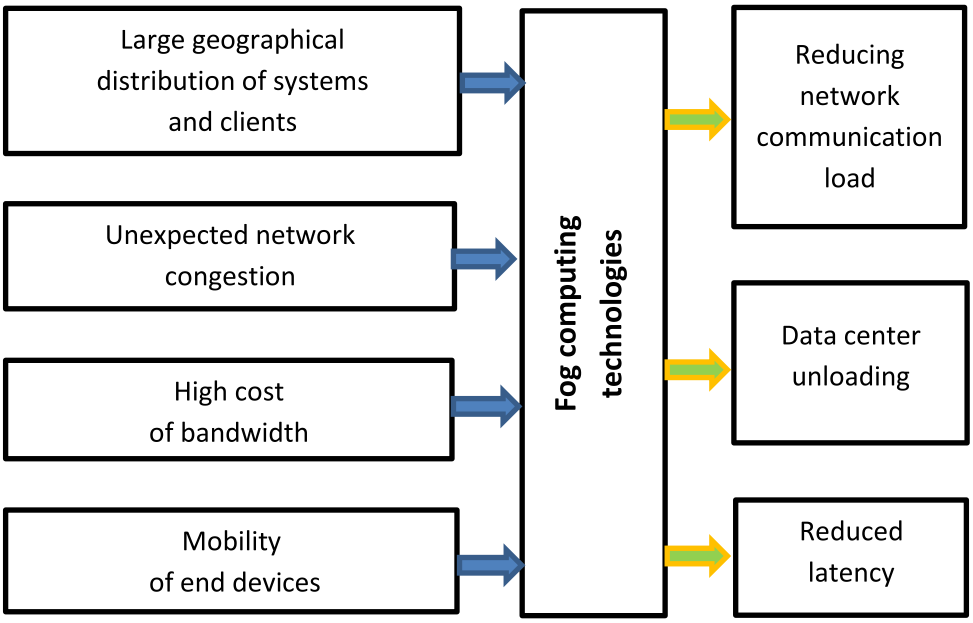

Fig. 2. Prospects for using fog computing technology to solve problems associated with the organization of the Internet of Things

Amazon offers the AWS IoT Greengrass fog computing platform, which effectively extends cloud infrastructure to fog layer devices, allowing data to be processed locally while using the cloud to manage, analyze and store the data. Such a platform allows you to programmatically filter device data and transmit only the necessary information back to the cloud [15]. Microsoft has proposed a solution for serverless computing – Azure Functions, which allows you to run small fragments of program code, or functions, in the cloud.

Azure functions provide data processing, system integration, working with the Internet of Things (IoT) and building simple APIs [5].

Google introduced the Android Things IoT platform with support for Intel Edison and Joule™ 570x microcomputers, NXP Pico i.MX6UL and Argon i.MX6UL, and Raspberry Pi 3 [6].

The company SONM has developed a multi-purpose decentralized platform for implementing complex computing tasks, based on blockchain and fog computing technologies [6].

Today, there are a wide variety of fog platforms, including private (Cisco IO, Nebbiolo Technologies, ClearBlade, Smartiply Fog, LoopEdge), public (Azure IoT, Amazon AWS IoT Greengrass, Google, Yandex and Mail.ru) and open source platforms. execution code (FogFrame2.0, FogFlow, FogBus) [7].

The key feature of fog computing technologies, which is to perform most of the data processing at the "edge" of the network, allows them to be used in a wide range of distributed systems, including monitoring and control systems, where system response time is one of the fundamental characteristics.

Monitoring and forecasting systems. In recent decades, the need to take into account information about the state of the environment has increased significantly. First of all, this is due to increased requirements for ensuring environmental safety, which, in turn, is the key to sustainable development of society. The intense impact of anthropogenic factors on the environment can cause various consequences, including negative natural phenomena that pose a danger to the population and various infrastructure facilities.

In this regard, it is relevant to use monitoring systems (MS) that ensure timely collection of data in order to notify the population about the expected occurrence of dangerous events [8]. The entire variety of currently existing monitoring systems can be divided into systems that do not process data, and systems that are capable of pre-processing data, thereby increasing the functionality of the system [9]. Currently, a promising direction for creating monitoring systems is the implementation of this class of systems based on "digital economy" technologies.

For example, Jonathan Bar-Magen Numhauser considers the problem of predicting natural hazards by processing large volumes of unstructured data generated by heterogeneous devices [1]. It is proposed to use fog computing technology to place some computing tasks on nodes of network equipment and mobile devices of organizations and individuals that are involved in monitoring. This technology allows you to reduce the load on the communication network and partially relieve the data processing center, which, in turn, increases the reliability of the system and reduces system latency.

The emergence of Internet of Things technologies and the development on their basis of "smart" cities, territories, enterprises and homes also contributes to the active implementation of monitoring systems in their infrastructure. Alex, er Slagg. [2] proposed a hierarchical distributed fog computing architecture to support the integration of a large number of infrastructure components and services in smart cities. As an example demonstrating the effectiveness of the proposed architecture, a prototype of an intelligent pipeline monitoring system in smart cities was implemented. Based on the results obtained, we can conclude that the use of fog technologies in the infrastructure of "smart" cities is promising, allowing them to significantly increase their "intelligence."

Erin Cunningham proposed an IoT-enabled intelligent water distribution and underground pipeline condition monitoring architecture for smart cities [3]. A key component of the developed architecture is the integration of Internet of Things technologies and fog and cloud concepts to effectively solve problems associated with automated water distribution, as well as monitor pipeline leaks.

Monitoring systems are actively used in agriculture. For example, Hamid Reza Arkian proposed an approach to data analysis and processing for distributed crop and soil monitoring, in which components that implement hierarchical data collection and modeling avoid problems associated with network bandwidth limitations and reduce the energy required for data transmission. Here the focus is on the use of fog computing technology, which allows the computing resources of local nodes to be used to further transfer partially processed data to higher levels of the system for decision making.

A model of a distributed library of a monitoring and diagnostic system for various areas of activity is also proposed (Fig. 3).

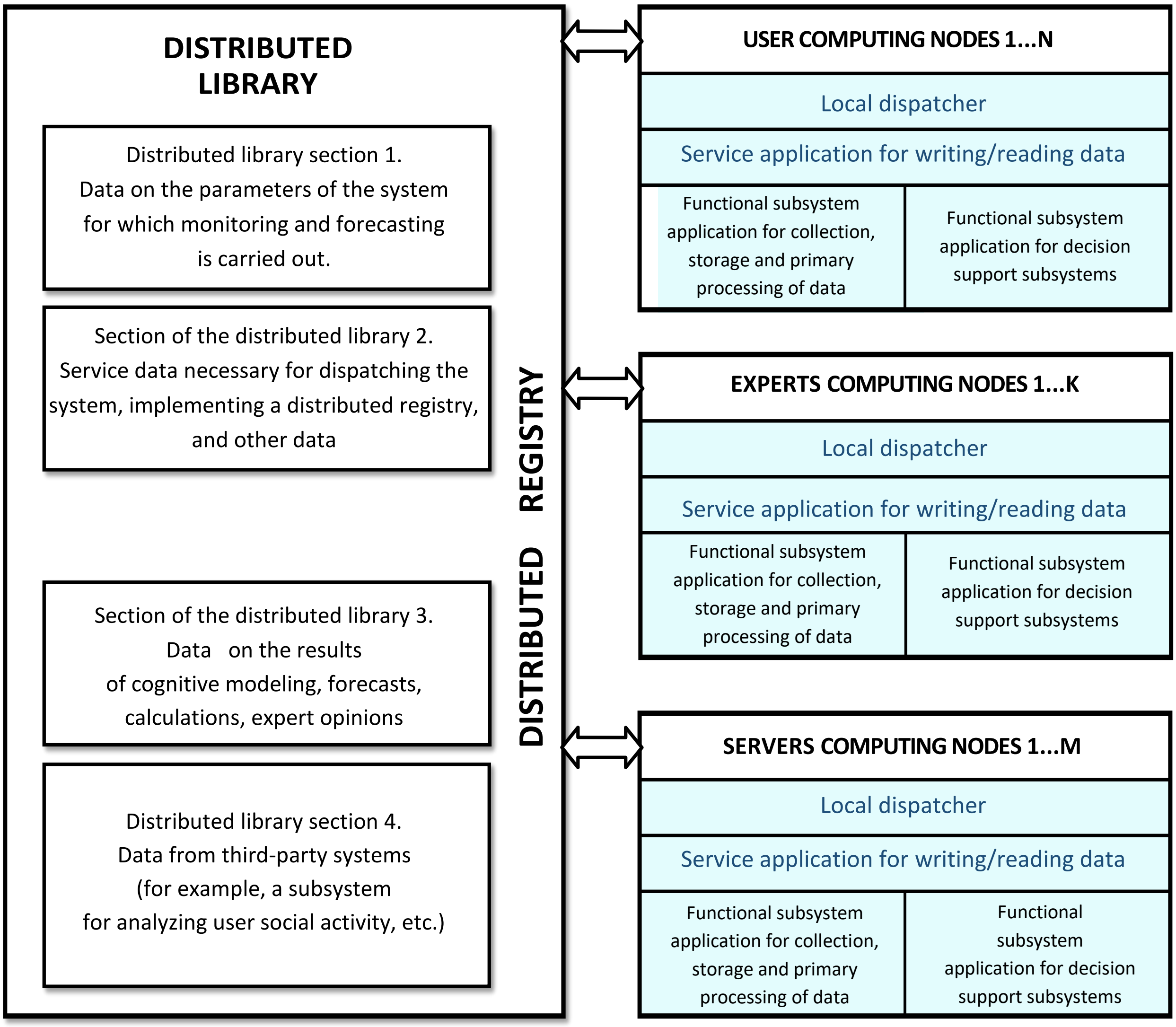

Fig. 3. Distributed library of monitoring and diagnostic system for various fields of activity

As can be seen from Fig. 3, the distributed library receives data from the data collection subsystem, their description, the results of their processing, after which they are available to users and experts. If necessary, the services provided by the subsystem can be executed on the cloud or fog computing layer. The decision support subsystem also has access to the distributed registry, and, therefore, to the data received from the collection subsystem. From this subsystem, data on the results of cognitive modeling and expert opinions can enter the distributed library. If necessary, simulation tasks can be executed on the computing nodes of the cloud and fog layers.

Conclusions

Thus, we can conclude that the construction of monitoring systems based on fog computing technologies is promising and effective in terms of reducing the load on the switching network, reducing system latency and partially unloading the data center for various areas of human activity, as evidenced by the above analysis.

References

1. Rehan M.M., Rehmani M.H. Blockchain-enabled Fog and Edge Computing: Concepts, Architectures and Applications: Concepts, Architectures and Applications. Taylor and Fransis, 2020. 302 p.
2. Jonathan Bar-Magen Numhauser. Fog Computing- Introduction to a new Cloud evolution. Proceedings from the CIES III Congress, January 2012 (англ.) // Escrituras silenciadas: paisaje como historiografía / José Francisco Forniés Casals (ed. lit.), Paulina Numhauser (ed. lit.), Proceedings from the CIES III Congress, January 2012.
3. Hamid Reza Arkian, Abolfazl Diyanat, Atefe Pourkhalili. MIST: Fog-based data analytics scheme with cost-efficient resource provisioning for IoT crowdsensing applications // Journal of Network and Computer Applications. – 2017-03-15. – Vol. 82. – P. 152–165. – ISSN 1084-8045. doi: http://doi.org/10.1016/j.jnca.2017.01.012
4. Kuchuk G., Kovalenko A., Komari I.E., Svyrydov A., Kharchenko V. Improving big data centers energy efficiency: Traffic based model and method. Studies in Systems, Decision and Control, vol 171. Kharchenko, V., Kondratenko, Y., Kacprzyk, J. (Eds.). Springer Nature Switzerland AG, 2019. Pp. 161-183. DOI: http://doi.org/10.1007/978-3-030-00253-4_8
5. Коваленко А. А., Кучук Г. А. Методи синтезу інформаційної та технічної структур системи управління об'єктом критичного застосування. *Сучасні інформаційні системи*. 2018. Т. 2, № 1. С. 22–27. DOI: https://doi.org/10.20998/2522-9052.2018.1.04
6. Nechausov A., Mamusuĉ I., Kuchuk N. Synthesis of the air pollution level control system on the basis of hyperconvergent infrastructures. *Сучасні інформаційні системи*. 2017. Т. 1, № 2. С. 21 – 26. DOI: https://doi.org/10.20998/2522-9052.2017.2.04
7. Iervolino, R., Manfredi, S. Global stability of multi-agent systems with heterogeneous transmission and perception functions. Automatica. 2024. 162, 111510. DOI: http://doi.org/10.1016/j.automatica.2024.111510
8. Кучук Н. Г., Мерлак В. Ю., Скородєлов В. В. Метод зменшення часу доступу до слабкоструктурованих даних. *Сучасні інформаційні системи*. 2020. Т. 4, № 1. С. 97-102. doi: https://doi.org/10.20998/2522-9052.2020.1.14
9. Shi, H., Lin, W., Liu, C., Yu, J. A Novel Heterogeneous Parallel System Architecture Based EtherCAT Hard Real-Time Master in High Performance Control System. Electronics. 11(19), 3124. Doi: http://doi.org/10.3390/electronics11193124
10. She R., Sun M. Security Energy Efficiency Analysis of CR-NOMA Enabled IoT Systems for Edge-cloud Environment. *Int. Journal of Computational Intelligence Systems*. 2023. Vol. 16(1), 118. DOI: http://dx.doi.org/10.1007/s44196-023-00273-y.
11. Петровська І. Ю., Кучук Г. А. Розподіл обчислювальних ресурсів у хмарних системах. *Системи управління, навігації та зв'язку*. 2022. Вип. 2 (68). С. 75–78. DOI: http://dx.doi.org/10.26906/SUNZ.2022.2.075.
12. Kuchuk G., Nechausov S., Kharchenko, V. Two-stage optimization of resource allocation for hybrid cloud data store. *Int. Conf. on Information and Digital Technologies*. Zilina, 2015. P. 266-271. DOI: http://dx.doi.org/10.1109/DT.2015.7222982.
13. Кучук Г.А., Коваленко А. А., Лукова-Чуйко Н. В. Метод мінімізації середньої затримки пакетів у віртуальних з'єднаннях мережі підтримки хмарного сервісу. *Системи управління, навігації та зв'язку*. Полтава . ПНТУ, 2017. Вип. 2(42). С. 117-120.
14. Sharma, M., Kaur, P. Reliable federated learning in a cloud-fog-IoT environment. *Journal of Supercomputing*. 2023. Vol. 79(14). P. 15435–15458. DOI: http://dx.doi.org/10.1007/s11227-023-05252-w.
15. Baucas, M.J., Spachos, P. Improving Remote Patient Monitoring Systems Using a Fog-Based IoT Platform with Speech Recognition. 2023. *IEEE Sensors Journal*. Vol. 23(15). P. 17611–17618. DOI: http://dx.doi.org/10.1109/JSEN.2023.3287916.
16. Essalhi, S.E., Raiss El Fenni, M., Chafnaji, H. A new clustering-based optimised energy approach for fog-enabled IoT networks. *IET Networks*. Vol. 12(4). P.155–166. DOI: http://dx.doi.org/10.1049/ntw2.12082.

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Технологія туманних обчислень в розподілених системах

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Анотація. **Актуальність.** Концепція туманних обчислень є еволюційним етапом у розвитку концепції хмари. Вона займає провідне місце серед загальних тенденцій розвитку інформаційних технологій. Виникнення цієї концепції тісно пов'язане з виникненням і розвитком концепції Інтернету речей. **Результати.** Проаналізовано предметну область. Він включає в себе аналіз сучасних тенденцій в області організації розподілених обчислень, аналіз використання алгоритмів популяції та моделей онтології для вирішення оптимізаційних задач у розподілених системах, аналіз моделей, методів і алгоритмів для вирішення задачі передачі обчислювальних навантаження в розподілених системах, реалізованих на основі туманних обчислень. **Висновок.** Виявлено, що концепція туманних обчислень дозволяє вирішити більшість проблем, пов'язаних із навантаженням на комунікаційну інфраструктуру та затримкою обміну інформацією. Але вони не вирішують проблеми, пов'язані з високою динамічністю туманного середовища та супутнім зниженням ефективності розподіленої системи.

Ключові слова: комп'ютерна система, розподілена система, туманні обчислення, хмарні обчислення, Інтернет речей.