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# ANALYSIS OF FOG COMPUTING CONSTRUCTION METHODS

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**Abstract.** The article presents an analysis of fog computing construction methods. Various topologies and architectures of this technology, devices and their application are considered. An analytical review of fog computing construction methods, the need to deploy a computing network as a set of successive blocks are given. Each block solves its own problem: defining requirements, choosing architecture, choosing software and hardware.
***Keywords:*** *Internet of things, methods of fog computing, fog computing architecture, IFCIoT architecture, open-Fog Architecture.*

**Аннотация.** В статье представлен анализ методов построения туманных вычислений. Рассматриваются различные топологии и архитектуры этой технологии, устройства и их применение. Приведены аналитический обзор методов построения туманных вычислений, необходимость развертывания вычислительной сети как совокупности идущих друг за другом блоков. Каждый блок решает свою задачу: определение требований, выбор архитектуры, выбор программного и аппаратного оснащения.

**Annotatsiya.** Maqolada tumanli hisoblashni qurish usullari tahlili keltirilgan. Ushbu texnologiyaning turli topologiyalari va arxitekturalari, qurilmalari va ularning qo'llanilishi ko'rib chiqiladi. Tumanli hisoblashni qurish usullarini tahliliy ko'rib chiqish va kompyuter tarmog'ini birin-ketin ishlaydigan bloklar to'plami sifatida joylashtirish zarurati berilgan. Har bir blok o'z muammosini hal qiladi: talablarni aniqlash, arxitekturani tanlash, dasturiy ta'minot va apparatni tanlash.

**Introduction.** The Internet of Things (IoT) is one of the fastest growing areas of infocommunications today. IoT has become widespread in many areas of human life: from security and healthcare systems to automation of industrial facilities and logistics management. Internet of Things systems are the main motivating aspect for the development of such areas as big data and their processing. Since IoT is a young concept, there is very little data for realistically forecasting the growth of traffic of such systems and networks. IoT traffic depends on the system that generates it. Even if there is data on the traffic generated by one elementary device, it cannot be described by a strict pattern. There are no statistics on peak hours, since this traffic aggregates with other types of traffic coming from data transmission networks. In other words, there is no modeling scenario. In order for forecasting to be possible and most accurate, it is necessary to consider how intelligent systems work as a whole, on what principle information is exchanged within such a system and outside it. To do this, the methods of information processing used in IoT systems are subject to study - calculations, namely, fog computing, which has become widespread due to the limited computing and transport resources. This study will consist of several parts, the first of which includes an analytical review of fog computing construction methods [1].

**Research object and methods.** Methods of fog computing construction. Logical implementation. The method is understood as a set of blocks - factors, each of which reflects the software and hardware implementation of the fog computing system. In other words, since Fog computing is a relatively new concept, there is no single reference model for fog implementation. Many researchers in this field provide their ideas for construction and models that are aimed at implementing Fog in one or another area of the IoT. Fog is defined as a computing process running on equipment that has direct contact with the physical environment and access to cloud computing servers. From the point of view of the architecture of computing networks, fog computing is a layer located between cloud computing and the physical world - the source of information and the control object. Vermesan O., Friss P. in the report "Internet of things - from research and innovation to market deployment" call fog computing an extension of the cloud (Micro Cloud), which is designed for the specific needs of some IoT device applications [2]. The following requirements for fog computing are defined: low latency; location awareness; wide geographic distribution; mobility; a very large number of nodes; the predominant role of wireless access; strong presence of streaming and real-time applications; heterogeneity. Fog computing is an extension of cloud computing to the network edges. The primary goal of fog computing is to reduce the computing load on the cloud by pre-processing big data generated by a network of devices: sensors, cameras, smart home systems, cities, enterprises.

**Models for building fog computing**

Fog computing is designed to be deployed in a distributed manner, where processing is performed by edge devices. Cloud computing is a more centralized concept. In fog, the data processing and storage devices are located in close proximity compared to the cloud, and this is the reason why fog is more capable of providing low-latency services (taking into account the latency through access points, smartphones, base stations, switches, servers, and routers). In addition, augmented reality, video streaming, gaming, and any other intelligent communication system also require transient computing. Each of these systems generates a large amount of data, which is not cost-effective to send to the cloud for further processing. The fog layer is defined as distributed intelligence that resides between the core network and sensor devices. Bonomi et al. also point out several characteristics that make fog a non-trivial extension of cloud computing. These characteristics include edge location, low latency, massive sensor network, very large number of nodes, mobility support, real-time communication, wireless dominance, interoperability, distributed deployment, operational analytics, and cloud interoperability. The model diagram is presented in Figure 1.

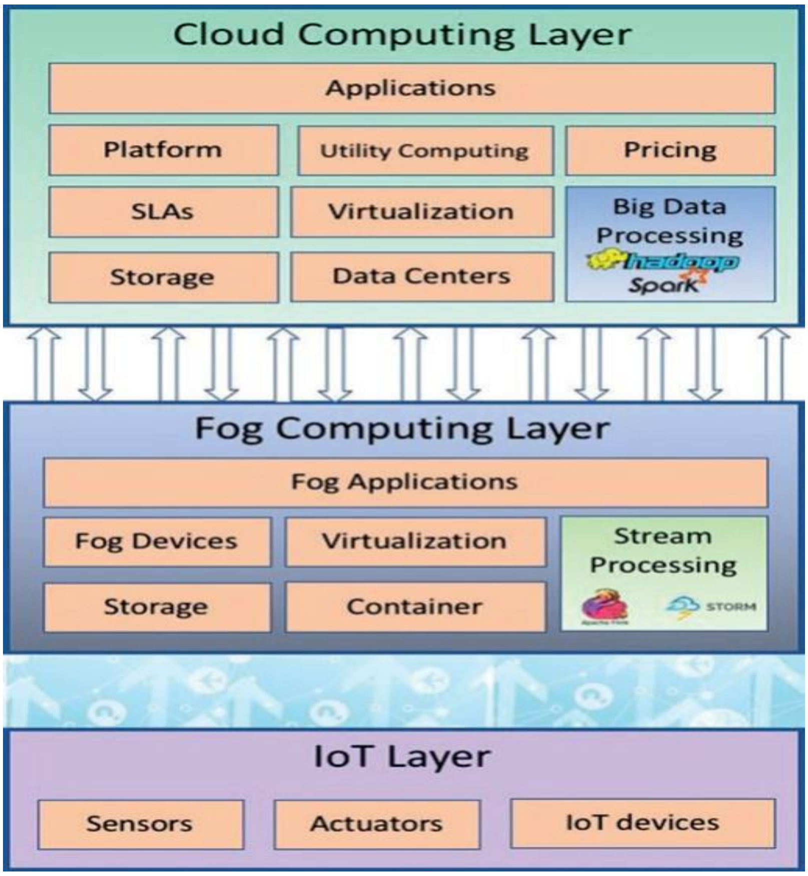


Fig.1. The scheme of interaction of the Fog level with the cloud and end devices

**Research results and their discussion. Fog Computing Architectures.** Layered Fog Architecture Aazam et al. presented a layered Fog architecture where layers were shown (Figure 2) [3,4]. The physical and virtual nodes and sensors are served as required by the lower layers known as the physical layer and the virtualization layer. The next layer up is the monitoring layer which monitors the network and the underlying node activities. This layer determines when and what task should be performed by which node. The same layer controls the energy consumption for the devices or nodes with constraints. Above the monitoring layer is the pre-processing layer which performs data management related tasks to obtain the required and more meaningful data.

The data is then temporarily stored in the fog resources in the next layer up known as the temporary storage layer. The topmost layer is the transport layer which uploads the pre-processed and secured data to the cloud. Thus, most of the processing will be done in the fog environment and will allow the cloud to deal with more complex services. Once the processed data is uploaded to the cloud, it is deleted from the local storage medium. For private data, the level of security is ensured by the confidentiality, encryption and integrity of the relevant services.

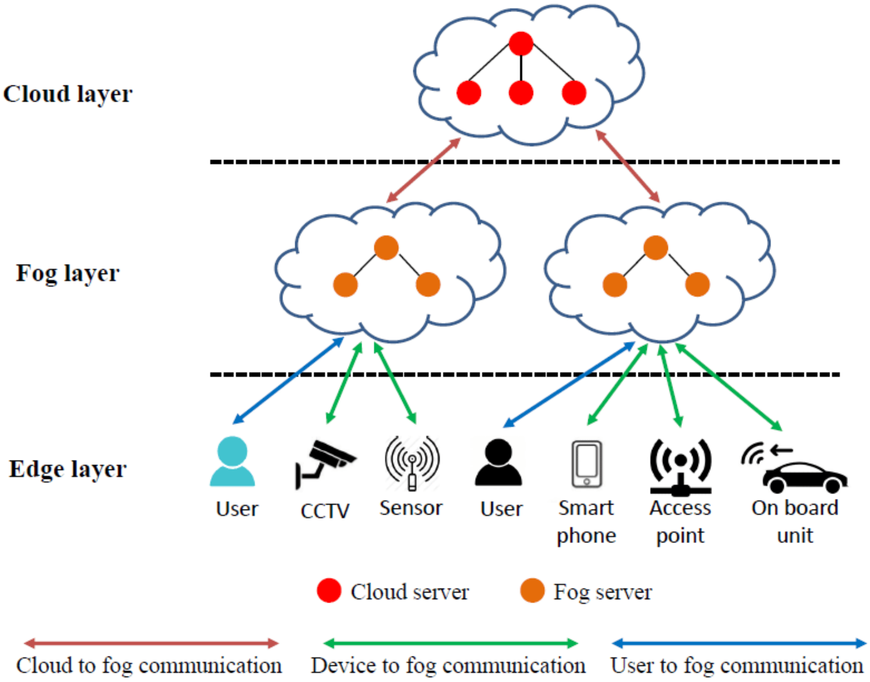


Fig.2. Fog computing architecture

Arkiyan proposed four layers of fog architecture: 1. Data generation layer; 2. Cloud computing layer; 3. Fog computing layer; 4. Data consumer layer. The data consumer layer considers a wide range of consumers, from individuals to enterprises. Consumers can send their requests to the other three layers and receive the required services. The data generator layer is where the IoT systems reside, which communicate with the cloud computing layer through the fog computing layer. In this architecture, the pre-processing of data will be performed in the Fog layer. This layer also provides context awareness and low latency. The cloud computing layer provides centralized management and a wide range of monitoring services. The key difference between this architecture and the others described above is the direct communication between consumers and all three layers [5].

The Fog layer is presented as an intermediate layer between mobile devices and the cloud in the fog system architecture of Luan TH et al. According to this architecture, the main component of the fog layer is the fog server, which is to be deployed at a fixed location at the local sites of mobile users. The fog server can be an existing network component, such as a base station or a Wi-Fi access point. These servers communicate with mobile devices over wireless connections and provide them with predefined application services in their wireless coverage without relying on the cloud or other fog servers. This system architecture does not take into account many other aspects, but it reveals the idea of the fog server. Dastjerdi presented a five-layer reference architecture for Fog computing. The topmost is the IoT application layer, which provides end users with the capabilities of these applications. The next layer is the software-defined resource management layer, which deals with monitoring, provisioning, security, and management. After that comes the layer responsible for managing cloud services and resources [6].

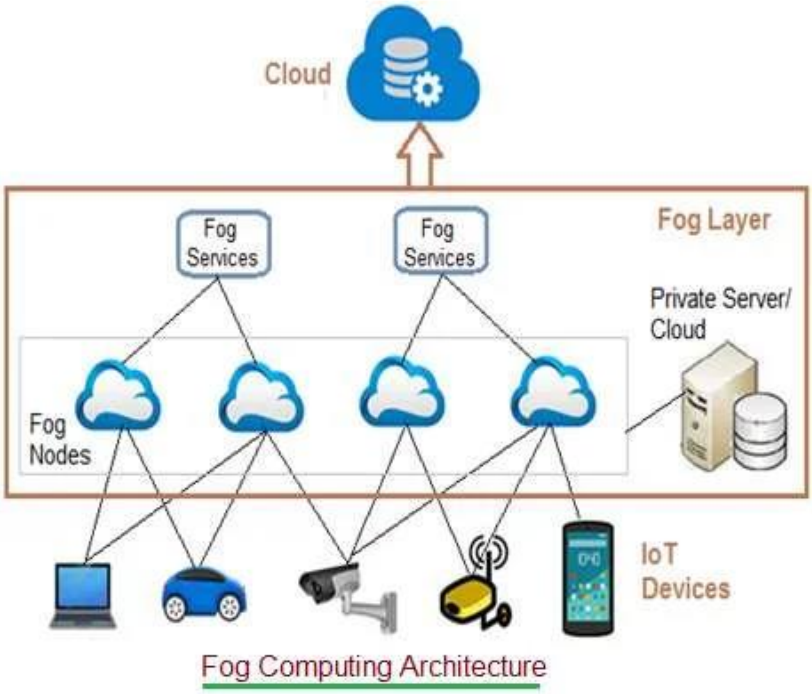


Fig.3. The architecture of the computer network of mobile devices

Next is the network layer, which supports communication between all devices and the cloud. The lowest layer consists of end devices such as sensors, edge devices, and gateways. It includes some applications. They work by improving the functionality of the device. In this reference architecture, the fog layer is completely absent, and it also does not indicate where the computation is performed [7].

**Scientific research results and conclusion. Hierarchical Models of Fog Computing.** Jang et al. presented a hierarchical fog architecture based on dividing fog devices into three different types: edge devices, compute nodes, and I/O nodes. Edge nodes perform primary data processing. I/O nodes are the generators of data in the system but have limited computing resources, so they maintain continuous communication with the edge nodes. Cloud nodes have large computing power and are dynamic with a programmable runtime environment. These three types of nodes can be implemented either separately or together, based on the requirements of the system being designed. A conceptual hierarchical fog computing architecture is presented by Hossain F. et al., [8] where the fog computing layer is divided into three sub-layers and can be expanded. Computation and data storage are performed at all layers except the bottom one. Layer 0 consists of sensors and actuators, layer 1 is called the fog gateway node, and layer 2 represents the main fog nodes [9].

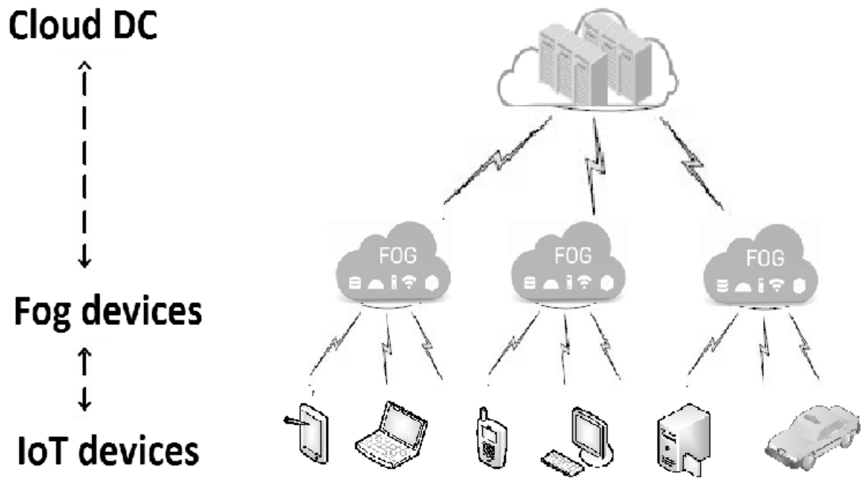


Fig. 4. Hierarchical model of fog computing architecture

## OpenFog Architecture

The OpenFog architecture is explained in its most comprehensive form in the research paper "OpenFog Architecture Overview" by Group OCAW5. OpenFog covers the main characteristics of fog computing. However, this architecture does not take into account the ability to store data close to the end users. It is designed to perform computations close to the client to minimize latency, transmission costs, and other network-related conditions along with bandwidth requirements. Controls, including configuration and access control, as well as network measurements, are deployed close to the endpoint rather than managed from the gateway. In addition, the proposed architecture enables data collection and processing using local analytics, and the results are securely copied to the cloud for further processing and use [10].

### IFCIoT Architecture

The Integrated IoT Cloud or Fog (IFCIoT) architecture was proposed by Munir in [11]. This architecture enables integrated cloud services for IoT devices through an intermediate fog infrastructure. The federated cloud is formed by multiple external and internal cloud servers that match the needs of applications and business. Gateway devices, smart routers, edge servers and base stations are fog nodes and most of the processing takes place in them. Fog nodes are autonomous; thus, each node can provide continuous service to its data providers. The entire deployment of the fog computing environment can be local in the case of automation of individual office buildings, and can also be distributed at a regional level including local levels in the case of large commercial companies located in several buildings in different locations. This architecture supports distributed deployment and transmission of information from different levels to a centralized system. The connection of all IoT devices is considered wireless connection through WLAN, WiMAX and other cellular networks. Fog nodes support the connection of IoT devices within their wireless range. The entire fog is connected to the integrated cloud service through the core network. For joint processing, the Fog system can be connected to other fogs wirelessly [12].

**Final conclusion.** In this research paper, the construction method is understood as a set of software and hardware, construction principles (architectures), and platforms designed to deploy a computing network. Fog computing is a new technology that is designed to solve the problems of running Big Data IoT applications by processing continuously generated data at the network edge. This computing paradigm is a high-potential model of a computing network that is developing rapidly. The main reason for the emergence of Fog was the Internet of Things, which has a large number of interconnected sensor networks generating big data. With the current speed of IoT development, the traffic of these networks significantly loads existing telecommunication networks. Its processing takes up a significant amount of data center performance. This leads to delays, errors, and failures in many time-sensitive applications. Fog computing is currently an opportunity to filter and significantly reduce the traffic of sensor networks before sending it to the cloud. In the future, part of the big data processing should move to the fog level, which will minimize the latency. The choice of the method for constructing an intelligent computing network cannot be fixed due to the large difference in the areas of application of such networks. Thus, it is necessary to consider the deployment of a computing network as a set of successive blocks. Each block solves its own problem: defining requirements, choosing architecture, choosing software and hardware.

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