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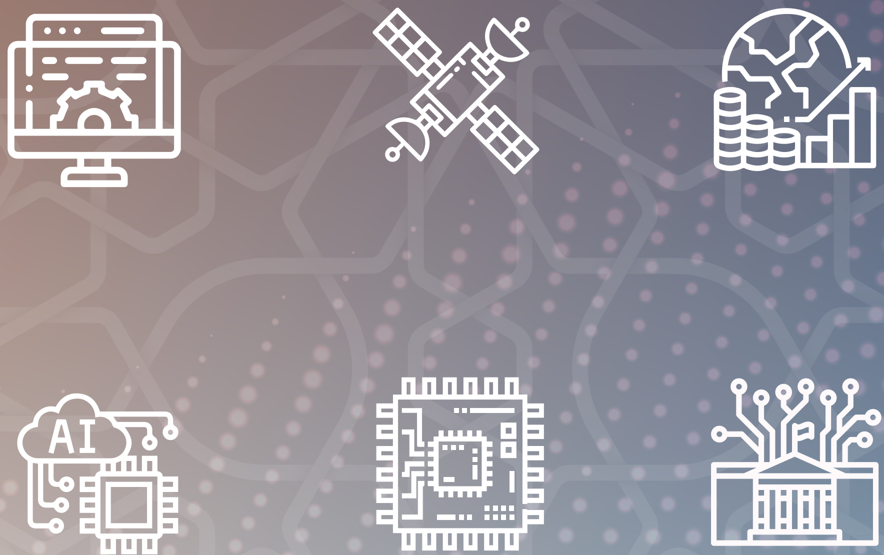

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Improving network management with Software-Defined Networking using OpenFlow protocol

With the development of network-based devices, communication networks also grow rapidly and become more complex, resulting in a large and heterogeneous network architecture that poses many challenges in network management. Therefore, network management is becoming more and more difficult given the existing network architecture. In this article, we'll look at how using the SDN OpenFlow protocol can improve network management.

Keywords: SDN, OpenFlow protocol, network, packet switching, I/O and time parameters.

I. Siddikov, H. Khujamatov, A. Temirov.

EDGE-FOG-CLOUD computing technologies in data processing in IoT-based energy supply system

This paper examines the advancements in edge, mist, and cloud computing that are being used to improve data processing for energy management systems in the Internet of Things (IoT). These advancements aim to address issues related to slow response times caused by limitations in network bandwidth, which occur due to the increased amount of data being transmitted between devices, power supplies, users, and the cloud. As the number of devices and ways to process their data within the IoT energy network continues to grow, there is a need for efficient energy data processing using edge computing, mist computing, and cloud computing technologies.

Keywords*:* IoT, Edge computing, cloud computing, fog computing, data preprocessing.

I. Introduction

As the Internet of Things (IoT) has become a part of our daily lives, the number of connected devices is growing rapidly. The approach based on embedded systems based on cloud computing technologies will certainly solve this problem when computing a large flow of data through IoT sensors. In such conditions, it cannot provide the required quality of service in terms of reducing the delay in data transmission. Edge and Fog computing technology is currently considered one of the promising solutions for processing large amounts of important and sensitive real-time data. The uniqueness of information interaction in the Internet of Things, the methods and algorithms based on them are fundamentally different from traditional computer networks, as a task of developing methods and algorithms that help to choose the optimal methods of interaction of things on the Internet defined.

Today, the IoT is one of the most important technologies, enabling the addition of automation and control to several industries, including transportation, healthcare, manufacturing, agriculture, energy, and infotainment. It works by installing sensors and actuators in various devices used in these sectors that allow real-time measurement of critical data. This data is transferred to special data processing servers, where it is possible to analyze it and act based on it by making intelligent decisions [1, 14].

IoT provides solutions for many important applications, including smart traffic management, safe autonomous driving, energy saving through a smart grid, remote patient monitoring, machine status monitoring, smart industrial automation, and smart home security. In the era of Industry 4.0 and 6G communications, IoT applications will revolutionize the way industries work [2, 12].

The number of IoT-associated gadgets is developing quickly each day. This makes it troublesome to productively prepare expansive sums of information produced by these gadgets. Cloud computing advances are ordinarily utilized to oversee this information stream, but they may not give the desired quality of benefit in terms of diminishing information transmission delays. Wide and cloud computing innovations are developing promising arrangements for the real-time handling of huge volumes of basic and touchy information. The area of edge-fog-cloud innovations for vitality frameworks that appeared in Fig.1. can be assessed. These technologies permit information preparation to require put closer to the source, decreasing the ought to send information back and forward to a central server.

Fig. 1. Edge computing architecture

As the demand for energy increases, there is a need for reliable and efficient energy management systems. By integrating edge-cloud-cloud computing technologies into IoT-based energy supply systems, real-time data measurement and operational efficiency can be improved. This is done by installing sensors and actuators in various devices used in these sectors. The number of sensors and actuators in this system can reach billions, which increases the computational complexity and energy consumption of the network. Processing, transmission, analysis and decision-making of IoT data allows for taking necessary measures to optimize the energy supply system. In summary, edge, fog, and cloud computing technologies are important in energy management systems within the IoT. They allow for real-time data processing, effective data storage and analysis, and decision-making on the optimization of energy supply systems.

II. Data processing tools

The decentralization of network infrastructure in energy supply systems presents challenges in maintaining fault tolerance and resource dynamics. IoT offers various use cases, including efficient power usage and data exchange between devices and networks. In energy management systems, reliable information and continuous provision of user energy consumption are crucial. IoT provides continuous monitoring, increasing equipment lifespan and operational efficiency. Real-time remote monitoring and application management are essential for energy conservation. IoT assets, or energy-saving applications, contribute to the creation of billions of interconnected devices. However, communication between these devices requires energy for receiving, transmitting, and storing information. High-performance IoT applications consume significant amounts of energy, which is a scarce resource. This study aims to reduce energy consumption in IoT-based applications, benefiting people by saving costs and energy. Fig. 1. illustrates the data processing approach in smart energy supply systems. It involves monitoring, analyzing, and optimizing energy consumers, residences, utilities, city services, and long-term urban planning.

Overall, edge, fog, and cloud computing technologies are crucial for efficient energy management systems within IoT. They enable real-time data processing, efficient data storage, and analysis, and informed decision-making to optimize energy supply systems.

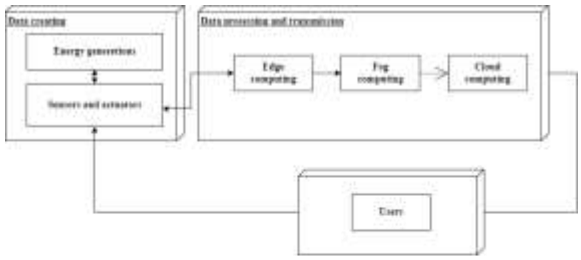

Fig. 2. Data processing and transmission model

To a computing paradigm that provides a universal approach to the organization of computing to solve practical problems that require high throughput of the energy supply system network, the ability to work with geographically distributed data sources, very low latency, and local data processing there is a common need. Cloud-closer computing nodes and connected device-based fog computing are proposed to bridge the gap between cloud and IoT devices by providing edge computing, storage, network, and data management for computing capabilities at nodes closer to the data source.

Data collection methods often have some shortcomings in data processing and are ineffectively controlled. This results in incorrect values, impossible data combinations, and missing data. Analysis of this unprotected data can lead to incorrect conclusions. The quality of the data comes first in the analysis. In most cases, a machine learning project is used for data processing. In the process of machine learning, the final result obtained with a large amount of redundant data, noisy and unreliable data is reduced or completely eliminated. Data preparation and filtering can take a long time. This problem is solved by pre-processing the data.

A. Edge computing

In a distributed energy system architecture, data is processed at the edge of the network, as close as possible to the data source. Placing computing and storage resources at the data production location is crucial. Ideally, computing and storage could also be collocated with the data source at the edge of the network. For instance, in Wind Power, a compact enclosure containing several servers and storage systems can be installed on the wind turbine to collect and analyze data from sensors on the turbine itself. It can consist of multiple computing devices and data storage systems for data collection and processing. The outcomes of this processing are intended for human analysis, archiving, integration with other data for broader analysis, and transmission to a data center [3, 15]. Fig. 3. shows the architecture of Edge computing.

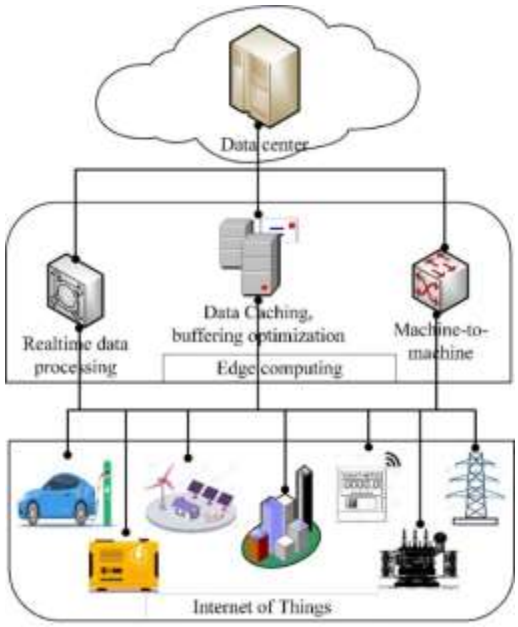

Fig. 3. Edge computing architecture

In traditional enterprise computing, data is typically generated at the client endpoint, such as a user's computer, and then distributed across a network for storage and processing in a centralized data center. However, this approach is not well-suited for handling the increasing volume of real-world data due to issues like limited bandwidth, latency, and network outages. To address these challenges, enterprises are adopting edge computing architectures. Edge computing involves moving some of the storage and computing resources closer to the data source, rather than sending raw data to a central data center. For example, in the context of energy systems, servers, and storage systems can be installed on wind turbines to collect and analyze data from sensors on the turbine. This allows for real-time processing and analysis of data at the edge of the network. The results of this processing can then be transmitted back to the central data center for further analysis and human interaction.

The shift towards edge computing is driven by the need to handle the ever-growing stream of real-world data more efficiently. By placing compute and storage resources closer to the point of data generation, enterprises can overcome challenges related to bandwidth limitations, latency, and network outages. This approach is particularly beneficial for industries like energy, where data is generated from various sources such as energy sources, smart meters, microgrids, and environmental sensors. Overall, edge computing represents a shift in focus from the central data center to the edge of the infrastructure. By moving storage and computing resources closer to the point of data generation, enterprises can better handle the increasing volume of real-world data and derive valuable insights in real time.

B. Fog computing

There are other options for deploying power system data storage outside the cloud and the edge. The location of a cloud data center could be quite far away. The installation of edge computing servers may be quite restricted in some systems. Physical distributed or hard-edge computing is made viable using this technology. Fog computing is a useful idea for this purpose [4, 13]. Storage and processing are split between edge computing and cloud computing in fog computing. The fog computing architecture is depicted in Figure 4.

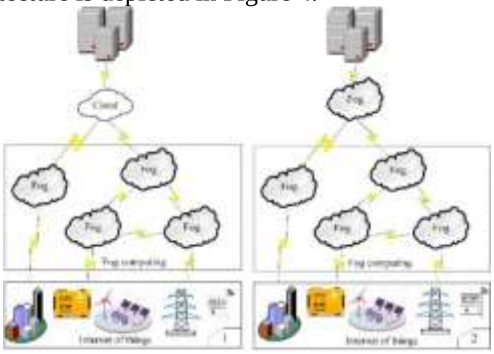

Fig. 4. Fog computing architecture

Fog computing environments are capable of producing significant amounts of sensor or IoT data over extremely broad physical areas with ill-defined boundaries. Several energy supply facilities, for instance, the smart grid, state energy account management, microgrid, branded energy supply, energy distribution systems, and continuous supply for consumers are only a few examples. It's possible that the load can't be supported by a single-edge installation. As a result, fog computing can solve some problems and offers the capacity to manage many deployments of fog nodes in a data gathering, processing, and analysis environment [5, 8].

C. Cloud computing

Through cloud computing, it provides scalable and reliable infrastructure resources that are resilient to large amounts of data errors. The public cloud architecture is divided into different layers with specific functions. At the physical layer, cloud infrastructure is supported by a collection of data centers that house a large number of application and storage servers. Private servers are dynamically provisioned and distributed among multiple users thanks to the virtualization layer. At the application layer, virtual machines are translated based on cloud performance. Cloud cost is the cost of performing a specific task within the cloud. A large, highly scalable deployment of computing and storage resources in one of several distributed global locations to store data coming through the energy supply system. Cloud providers include preconfigured services for IoT operations, making the cloud the preferred centralized platform for IoT deployments. turns Figure 5 shows the cloud computing architecture [6].

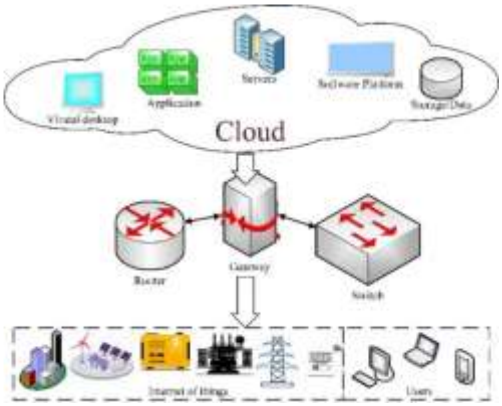

Fig. 5. Cloud computing architecture

But even though cloud computing offers enough resources and services to handle complex analytics problems, the nearest regional cloud center may be hundreds of miles away from the data collection point, and the connections support traditional data centers. depends on the same unstable Internet connection that powers it. In practice, cloud computing is an alternative, and sometimes a supplement, to traditional data centers.

III. Results and discussion

The terms "fog computing" and "edge computing" are used interchangeably in many places because they have many similar features, but there are some differences between them. Table I shows the main differences between cloud, fog and edge computing.

Table 1.

The main differences between cloud, edge, and fog computing

Difference	**Cloud computing**	**Edge computing**	**Fog computing**
Data processing	Cloud servers are at a great distance from the source of information	processed by computing systems located near connected devices or sensors	Processed by processors connected to the local network, these processors may be some distance away from the sensors that generate the data
Architecture	Follows a centralized model where data is stored on central servers and services are provided to the customer based on the concept of pay-as-you-go	Follows a decentralized model in which data is stored on edge devices and processed by the same	Follows a decentralized model in which data is stored on edge devices close to the network and processed by the same

Scaling	It can store big data and perform analysis on it. In addition, it provides on-demand scaling functionality, meaning it is easy to scale	It can only store locally accumulated data, storing and analyzing big data becomes difficult on peripheral devices. Therefore, they are less scalable compared to cloud computing	Its main purpose is to provide real-time data processing. After processing the data, it sends the result to the cloud for further analysis. Thus, they have limited scalability compared to cloud computing
Application	Used for long-term data analysis to generate reports, identify patterns	It is used for faster data analysis of latency-sensitive applications	It is used for faster data analysis of latency-sensitive applications
Nutrition and storage	More powerful than fog computing and edge computing because they have superior capabilities	The amount of peripheral computing is reduced, because here the processing and storage takes place in the devices themselves.	Limited memory and processing power
detain	Output latency is highest in the case of cloud computing due to the large distance between sensors and processing devices.	This is minimal in the case of edge computing due to the smaller distance between sensors and processing devices.	This is slightly higher than edge computing due to the distance between sensors and processing devices.

Computational tasks require an appropriate architecture, and an architecture suitable for one type of computational task may not be suitable for others. Edge computing has emerged as a viable and important architecture supporting distributed computing to deploy computing and storage resources closer to the data source. Ideally located in the same physical location as the data source. The emergence of smart meters and microgrid control units for energy supply systems will depend on the intelligent systems of the infrastructure. Energy accounting and adaptive management systems will need to receive, analyze and share data in real-time. The scale of the problems that can arise as a result of the increase in autonomous sources of this demand becomes even more obvious. This requires a fast and responsive network. Edge, fog, and cloud computing are expected to address key network constraints: Transferability, latency, and congestion or reliability [7, 9].

Transferability. Bandwidth is the amount of data a network can transmit in a given time interval, usually expressed in bits per second. All networks have limited bandwidth, and these limitations are more severe for wireless communications. This means that the amount of data or the number of devices that can transmit data over the network is limited. While it is possible to increase network bandwidth to accommodate more devices and data, the costs can be significant, there are still high limits, and this does not solve other problems.

Latency. The time it takes to transfer data between two points on a network. Ideally, data would be exchanged at the speed of light, but long physical distances combined with network congestion or network failures can delay the movement of data across the network. This delays any analytical and decision-making processes and reduces the system’s ability to respond in real time. For critical facilities of energy supply, the limitation of the operation of the system can be expensive.

Traffic jam. The Internet is essentially a global network of networks. While it has evolved to offer good general-purpose data exchange for many everyday computing tasks, such as file sharing or basic data transfer, the amount of data associated with billions of devices is overwhelming on the Internet. and this large amount can cause a blockage. Data transfer time In other cases, network outages can increase traffic and even completely disconnect some Internet users, making the Internet unusable during the outage.

By deploying data production servers and storage, edge computing can handle multiple devices on a much smaller and more efficient LAN. High bandwidth is used only by local data processing devices, which virtually eliminates latency and congestion. Local storage collects and protects raw data while allowing edge servers to perform critical analytics at the far edge, or at least pre-process, minify, and send some simple data from the results to the cloud or data centers. used for real-time decision-making before [10].

A. Data processing method

Information overload is one of today’s challenges, and therefore, acquiring more data and processing it efficiently requires more cost and effort in big data-based energy supply systems. The proposed model in Figure 6 provides for solving the problem of reducing the amount of energy in processing for energy supply systems.

With the emergence of response-time-sensitive energy consumers in power supply systems, the remote cloud cannot meet the need for ultra-reliable, low-latency communications of these applications [11,16]. Also, some apps may not be able to send data to the cloud due to privacy concerns. These connected devices generate large amounts of real-time data through IoT sensors and transmit it to servers.

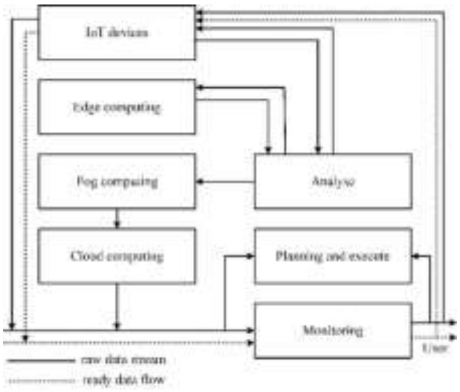

Fig. 6. Data processing architecture

Today's existing communication data architectures are designed to take into account the load that occurs when transmitting and processing such an astronomical amount of data. In current implementations of cloud applications, most of the data that requires data generation, storage, analysis, and decision-making is sent to data centers in the cloud. As the amount of data increases, the need to transfer data between the IoT device and the cloud becomes inefficient or in some cases introduces errors that may occur due to bandwidth limitations or latency requirements [17].

B. Comparison of edge, fog, and cloud computing technologies

From a practical point of view, based on the need to create and return data in data transmission and processing, Table II examines the main differences in data transmission between edge, fog, and cloud computing technologies.

Table 2

A comparison of edge, fog, and cloud computing in data flow representation

Characteristic	Edge	Fog	Cloud
Placement	Scattered	Scattered	Centralized
Components	Edge nodes	Fog nodes	Virtual resources
Location awareness	+	+	-
Calculation	Limited	Limited	Unlimited
Save	Limited	Limited	Unlimited
Information	Process	Process	Process
The distance to the data source	The closest	Close	Long
Response time	The fastest	Quick	Slow down
Nodes are counted	Very big	Big	Small

In the relative distribution of computing resources defined by the concepts of edge, fog, and cloud computing, cloud computing is a separate data processing center or a network of data centers located far from the user, but providing high computing capabilities. On the other hand, edge computing is located directly at the edge of the computing system and provides less computing power, but is located close to the consumer of these resources. Fog computing is located between the edge of the network and the cloud data center, providing critical computing resources close to the end user, on the other hand, it is not comparable to the overall size of cloud computing but can be customized and scaled.

Conclusion

The analysis of this study shows that the use of edge, fog, and cloud computing technologies in a hybrid state reduces the confusion that often occurs by combining the concepts of fog and edge computing within the framework of considering their evolutionary development and key features. As a result of the analysis, we found that the dynamic changes of edge computing, and fog computing will lead to the disordered state of the network topology, and the collision of data sources when accessing Internet of Things resources in fog and cloud computing. Heterogeneity, the demand for energy efficiency, and the possibility of data exchange in the Internet of Things. affect temporal characteristics. When designing energy supply systems through IoT, it is necessary to consider these problems and create new methods and algorithms that allow obtaining optimal solutions for the organization of information interaction in the conditions given for the operation, taking into account the specifics of the work.

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IoTga asoslagan energiya ta'minoti tizimida ma'lumotlarga ishlov berishda edge-fog-cloud computing texnologiyalari

Ushbu maqolada Internet of Things (IoT) ga asoslangan energiyani ta'minoti tizimlari uchun ma'lumotlarni ishlov berishning yaxshilashi uchun foydalaniladigan edge, fog va cloud hisoblash sohasidagi yutuqlarni ko'rib chiqadi. Ushbu yutuqlar qurilmalar, quvvat manbalari, foydalanuvchilar va bulut o'rtasida uzatiladigan ma'lumotlarning ko'payishi natijasida yuzaga keladigan tarmoq o'tkazuvchanligidagi cheklovlar tufayli yuzaga keladigan javob vaqtlarining kechikishlari bilan bog'liq muammolarni hal qilishga qaratilgan. IoT asosidagi energiya tarmog'ida qurilmalar soni va ularning ma'lumotlariga ishlov berish usullari o'sishda davom etar ekan, edge, fog, cloud hisoblash texnologiyalaridan foydalangan holda energiya ma'lumotlarini samarali qayta ishlashga ehtiyoj bor.

Kalit so'zlar: IoT, Edge computing, bulutli hisoblash, tumanli hisoblash, ma'lumotlarni oldindan qayta ishlash.