American Journal of Interdisciplinary Research and Development
ISSN Online: 2771-8948
Website: www.ajird.journalspark.org
Volume 08, Sep., 2022

USING OF EDGE/FOG/CLOUD COMPUTING TECHNOLOGIES IN SMART GRID INFORMATION FLOW MANAGEMENT

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Abstract
This article is an integral part of the modern life of the information society. Currently, one of the main directions of their development is the implementation of the concept of building the Internet of Things (IoT). The development of IoT includes both information and information technology acquisition technologies and the development of channels and communication networks for data transfer between these network elements.

Keywords: IoT, smart grid, fog network nodes, data processing.

Introduction

IoT networks are mainly defined by the characteristics of practical problems and their application areas. These features consist of methods of obtaining information and shaping the messages to be transmitted, and methods of constructing the IoT networks themselves. The latter can be built as information collection (monitoring) networks and information distribution networks. One of the characteristic features of IoT networks is the high density of devices (network nodes), which can be several times higher than the density of subscribers in modern mobile networks. This feature has been described several times in the work on the construction of IoT, but it should be noted that the distribution of the density of subscribers is very uneven across the planet, continents and even countries. Almost all countries of the world have regions with high and low subscriber density. The density of the IoT network may have different densities in different regions and areas, as well as under different operating conditions. Over the past few years, we have witnessed the emergence of the Internet of Things (IoT) ushering the world into a new era of communication. Recent technological advancements have enabled machines and devices to save and influence human life everywhere, both in terms of hardware and software. In this context, machine-to-machine communication (M2M: machine to machine), the exchange of data between devices automatically through wired and wireless channels, has become the typical paradigm of IoT [1]. Thus, the simultaneous connection of billions of objects has led to a rethinking of the global network concept.

I. Analysis of IoT issues

The above characteristics of the traffic, as well as the structural characteristics of the IoT network, require the development of models and methods that allow the implementation of IoT functions in various conditions, as well as ensure coexistence with existing and prospective communication networks [2]. The topic of the work is relevant because it is aimed at solving these problems. "Table. 1" summarizes IoT challenges.

Table.1. IoT challenges

Emission categories	Special issues
Security issues	• Security Platform Design • Confidentiality of information • Standards and indicators • A balance between cost and security • Ability to save and update
Privacy Issues	• Data Collection and Use • Privacy Requirements and Benefits • Regulatory design
Technical difficulties	• Latency and data preprocessing • Organization of the ecosystem • Technical costs • Improperly designed devices • Standardization • Configuration
Regulatory, legal and legal issues	• Data protection (including cross-border) • Civil rights and public safety • Data discrimination • IoT Liability • Legal Assistant
Emerging economies and development issues	• Organization of infrastructure • Capital • Technical and industrial development • Coordination of policy and regulation

This data fusion technique directly affects the comparison and evaluation steps, and thus a crucial question arises: how can we fuse sensor data locally without compromising the accuracy of the overall decision? can we A secondary question addresses the feasibility of distributing processing, given that many network and edge devices have less processing power.

II. Technologies for information management systems

The choice of data processing location on the network is important to ensure network utilization and data processing efficiency. Therefore, we propose an efficient approach that moves the computation to the fog/edge side of the network as much as possible "Fig. 1".

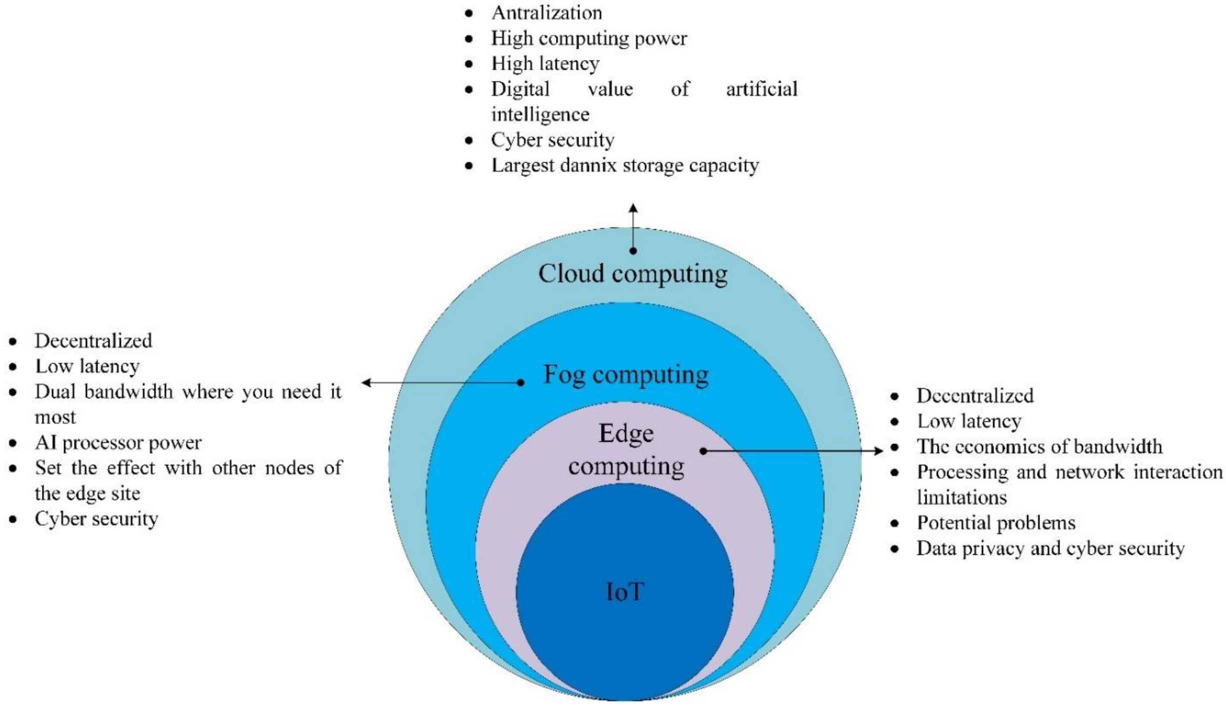

Fig.1.Description of data processing methods

It is important to move some of the data processing closer to the data source because IoT devices are limited and processing some services may require high computing power based on experiences [3-5]. As a result, we investigate the feasibility of using data fusion techniques over resource-constrained devices such as the Raspberry Pi 3 Model B.

Cloud computing. This is the highest level of the paradigm. It has the computing resources and storage capacity that allows the IoT application developer to store and analyze the data transmitted by the Cloud nodes. It is also responsible for managing, monitoring and coordinating the entire fog paradigm [6].

Fog computing. This is the middle level of the paradigm. Widespread fog nodes and network infrastructure make up this layer. Provides the proximal edge calculation for the bottom layer. Here, data collected by user devices and sensors are pre-processed [7-9]. It differentiates between sending the data to the Cloud or processing the data in the Cloud node and returning the result or orders to the user devices or actuators. The virtualization function is also implemented in this layer [10].

Edge Computing. A distributed information technology (IT) architecture in which customer data is processed at the edge of the network, as close as possible to the source.

Applying data fusion to data from IoT devices close to the data source is important in big data processing, so we argue that combining big data before sending it to the cloud can save network usage by sending only more meaningful data.

These connected devices form the Internet of Things (IoT) and generate large amounts of data in real time. Today's mobile network architectures are already being designed with the loads that occur when transmitting and processing such astronomical amounts of data.

In current implementations of cloud applications, most of the data that requires storage, analysis, and decision making is sent to data centers in the cloud [11-13]. As the amount of data increases, data transfer between an IoT device and the cloud may not be efficient or in some cases impossible due to bandwidth limitations or latency requirements. With the emergence of response time-sensitive applications (e.g., patient monitoring, self-driving cars, etc.), the remote cloud cannot meet the need of these applications to provide ultra-reliable, low-latency communications [14]. In addition, some applications may not be able to send data to the cloud due to privacy concerns.

Since fog computing is a very new concept, there are many challenges that need to be addressed. Most of the challenges can be divided into several aspects below.

- **Technical test.** Computing size and storage limit. Fog computing plays as an extension of the cloud. Considering the price, its capacity and storage are limited. How to balance performance and cost is a conundrum for Fog Computing.
- **Resource management.** It is estimated that there will be billions of end devices connected to the Fog network and the number will continue to grow. As the resource in Fog server is limited, how to effectively configure, manage and configure the resource for Fog server is very difficult.
- **Programming model.** Several types of IoT applications run on or connect to the Fog server. Since Fog Server aims to provide an open source system for developers, an appropriate programming model is needed to facilitate the efforts of developers.
- **Drop the bills.** Fog computing supports mobility, especially the high mobility scenario, making it a highly dynamic network. With limited resources on a single

server, offloading technology is important to ensure performance and maximize resource utilization for Fog servers.

- **Physical placement.** Efficient fog server deployment improves and maximizes fog computing performance and reduces infrastructure costs.
- **Energy minimization.** Because a large number of Fog servers are deployed in a large area. Energy consumption is not a trivial problem.

There is a common need for a computing paradigm that provides a universal approach to organizing computing to solve application problems that require high network bandwidth, the ability to work with geographically distributed data sources, ultra-low latency, and local data processing. based on computing nodes in the cloud and closer to connected devices. The concept of fog computing (fog computing) has been proposed by the industrial and scientific community to bridge the gap between the cloud and IoT devices by providing computing capabilities, storage, networking and data management at network nodes close to the IoT [15].

The research community has proposed a number of similar computing paradigms to solve the mentioned problems, such as edge computing (eng. Edge computing), mist computing (eng. Mist computing), dew computing (eng. Dew computing) and others. In this review, we examine fog computing and the technologies that support it, and argue that fog computing is a general form of computing, mainly because of its comprehensiveness and flexibility [16-18].

In this study, an architecture was developed for the generation of information flow and efficient processing of this flow using IoT technology for Hybrid energy supply sources (Figure 2).

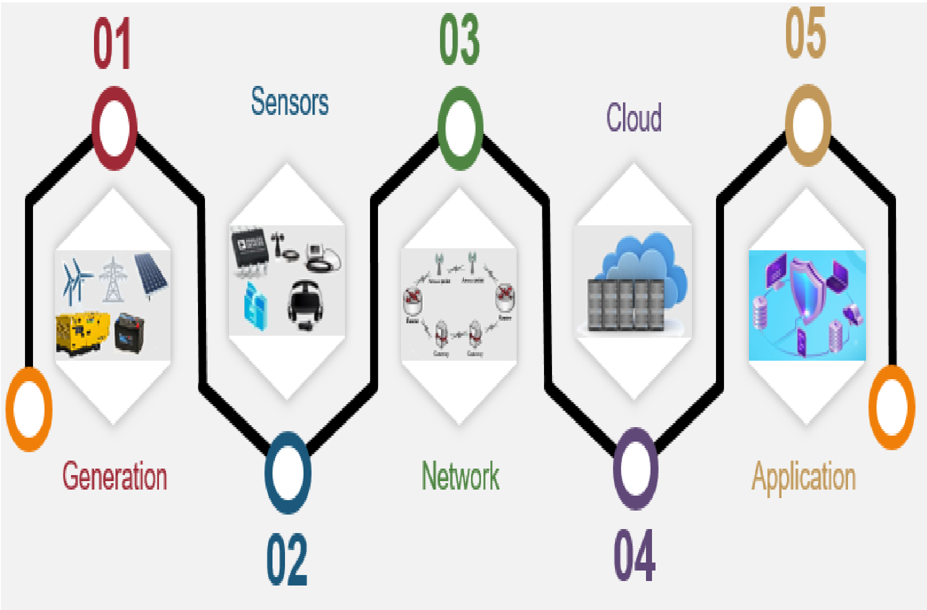

Fig.2. Information management architecture of IoT-based Smart grid system

Now let's take a look at each layer of the above architecture:

Layer 1. Generation. Including the task of energy development and delivery, it is possible to mention power plants such as sources of electric energy (solar, wind, centralized energy sources, accumulator battery, diesel generator).

Layer 2. Sensors. Connected devices (sensors/actuators). The good thing about sensors is that it can convert the information it senses into a data set that it can process for later analysis. This process is more suitable for actuators. They can make decisions and take actions based on automatically collected information. In this layer, additional hardware can be used and the necessary data for further analysis is obtained from the methods.

Layer 3. Network. Acquisition of sensor data. At this layer, IoT is understood to deal with sensors and actuators located near it. Internet gateways and data acquisition systems (DAS – Data Acquisition Systems) play an important role here. DAS units are connected to the sensor network. Internet gateways, on the other hand, work with Wi-Fi, wired LANs, and perform post-processing.

Layer 4. Cloud. This layer is important for processing the information collected in the previous layer and compressing it to an optimal size for further analysis. On top of that, time changes and structure changes are made at this stage. In a nutshell, layer 3 helps to collect and digitize data.

Layer 5. App. The application layer used for data analysis, visualization and storage is considered. Here, at the last stage, the data is deeply processed in the data centers. This layer requires skilled IT professionals along with highly finished applications. Data may also be collected from other sources for performance purposes. After all quality standards and requirements are met, the data is fed back to the physical layer for predictive analysis.

As a disadvantage of this approach, we can note that the radical decentralization of network systems, the absence of a single network address space and a single administrator of the main computing infrastructure make it difficult to ensure fault tolerance and end-to-end dynamic management of available resources users [19]. These shortcomings led to further evolutionary development and the emergence of cloud computing, which often uses a grid computing model to expand computing resources [20].

Due to the disadvantages of each type of deployment, cloud providers to private companies often set up specific hybrid clouds [21-22] that can pretend to be private or public on demand, resulting in data transmission delays, eliminates security and migration issues. as an elastic adjustment of computing resources for each required task.

Table.2. System options

Field requirements	Fog capacities	Fog restrictions and challenges
Industry 4.0	• Fog interface • risk complexity • improve high constrained system performance	• risk safety • risk complexity
Industry automation	• Realtime communication • improve high constrained system performance • Data preprocessing • integrated flow control system	• sustainability
Heterogeneous system	• Integrated flow control system • low latency • Heterogeneity	upgradable
Data misunderstanding	• Less segregation automation pyramid • facilitate the transfer of data • Data preprocessing	balance of cost and effectiveness

III. The main features of fog computing

Since the concepts of fog and edge computing have been separated of late, many companies have provided their own specifications [23] and definitions for fog and edge computing. In 2017, the OpenFog consortium released a reference architecture for fog computing based on eight key principles: programmability, hierarchy, flexibility, serviceability (Reliability, Availability and Serviceability - RAS), availability, reliability, autonomy, openness and security [24]. the following main characteristics of fog computing are covered.

- Location Awareness and Low Latency - Fog nodes are aware of their logical location relative to each other, allowing them to calculate the time it takes to communicate with other nodes.
- Geographic distribution - fog services and applications are able to work with gateways located in different geographical locations, through which connection to the fog is made.
- Heterogeneous data support - support for the collection and processing of data in different formats obtained using different types of network communication capabilities.
- Interoperability and Federation - Cloud components must be able to communicate with each other regardless of their differences, and services must be distributed across different domains to ensure access.
- Real-time interactions - Fog applications should work in real-time rather than bulk request processing.
- Scalability and Agility of Federated, Cloud Clusters - Cloud computing must be inherently flexible. The following basic adaptation mechanisms should be

supported: computational flexibility, pooling resource capacity, adapting to changes in data load and changing network conditions.

In the fog computing paradigm, fog nodes are located at the edge of the local network, often they are placed on the basis of routers, wireless access points (if these devices support the necessary technologies for fog node placement) [25]. Unlike fog computing, edge computing is placed "closer" to the end devices, at intermediate access points already in the local network itself, and sometimes the end devices themselves can act as edge computing nodes: smartphones, tablets, enough computing support the deployment of other computing devices and computing nodes with the ability [26]. However, this simultaneously limits their computing power, and therefore there are some limitations in their application. Currently, edge computing is used to solve problems such as video surveillance, video caching, and motion control [27].

Clouds are located in the data center, where the equipment is designed for extreme workloads. However, the server equipment is not always fully loaded, which does not allow it to be used effectively. The main technology supporting cloud and then fog computing is virtualization technology [28], which allows the resources of a single physical machine to be used by multiple logical virtual machines (VMs) at the Hardware Abstraction Layer (HAL) level. Virtualization technology uses a hypervisor - a software layer that ensures the operation of virtual machines based on hardware resources. The machine with the hypervisor is called the host machine. A virtual machine running on a host machine is called a guest machine, which in turn can host guest operating systems (OS). This type of virtualization is called hypervisor-based virtualization.

Container-based virtualization [27], which is a set of packaged, self-contained, deployable application components that may also contain business logic in the form of binaries and libraries for running middleware and applications.

[28] presents a comparative analysis of both types of virtualization, based on which some advantages of container-based virtualization can be distinguished.

Hardware resources. Container-based virtualization reduces hardware costs through consolidation. This allows parallel software to take advantage of the true parallelism provided by multicore hardware architectures.

Scalability. A container management system can efficiently manage a large number of containers, allowing you to create additional containers as needed.

Spatial isolation. Containers support lightweight spatial isolation by giving each container its own resources (such as CPU core, memory, and network access) and container-specific namespaces.

Save. Containers are lighter than virtual machines.
Applications inside containers share binaries and libraries.

Work. Compared to virtual machines, containers have higher performance (end-to-end) because they do not emulate hardware.

Portability. Containers support easy migration from production environment to production environment, especially for cloud applications.
Thus, two main virtualization technologies are currently used to support fog computing [31].
A case study for a Smart grid network is chosen to demonstrate the application of our architecture. The analytical values of our analytical study comparing edge, fog and cloud computing technologies are presented in Table III.

Table.3. Edge/fog/cloud features of the system used in the smart grid system

Main character activity	**Edge Analytics**	**Fog Analytics**	**Cloud Analytics**
Data flow	• Input: raw data • Output: collected and processed data	• Input: summarized and processed data • output: contextual and aggregated data	• Input: contextual and aggregated data • Output: Predicted Values
Delay	Low	Medium	High
Data speed	High	Medium	Low
Resources	Limited	Medium	High performance on demand
Geographic distribution	local	Regional	Global
Expandability	High	High	High
Statistical results and conclusions	high speed	medium speed, accuracy	large data collection
Ability to work in real time	in real time	Almost in real time	Periodic

In addition, container-based virtualization is becoming more widespread due to the low hardware performance requirements to ensure the placement of computing nodes on intermediate devices that may not have high computing power, which is especially important for edge computing. they are launched not even on IoT devices themselves [32] but on intermediate access points closest to the devices.

Conclusion

When containerization began to develop as one of the technologies to support cloud computing, the issue of managing the computing load to ensure the efficient use of geographically distributed resources arose. The implementation of fog computing requires solving the problem of managing computing resources at a different level compared to, for example, cloud computing. It is necessary to ensure the identification of physical and virtual cloud devices, as well as the resources associated with them. The orchestration of a fog computing environment must support a single set of protocols, standard interfaces, and ontologies. It allows different nodes and applications in the system to communicate with each other. One of the primary functions of A is to reduce transmission and processing delays. This is achieved through intelligent mechanisms of data flow optimization and resource planning. Continuous interaction between all participants of the cloud environment should be ensured, regardless of possible failures and problems, both at the physical and logical levels. By collecting, storing, and analyzing the performance of system nodes, an orchestration system can optimize data transmission routes and device interactions to meet latency and quality of service requirements.

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