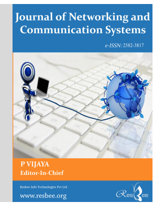
Vol.5 No.2 April 2022

Journal of Networking and Communication Systems

Received 13 December, Revised 11 February, Accepted 26 March



Distributed Edge Computing in SDN-IoT Network

Seyedeh Shabnam Jazaeri
Department of Computer Engineering, North Tehran Branch, Islamic Azad University, Tehran, Iran

Elham Taghdiri
Department of Computer Engineering, North Tehran Branch, Islamic Azad University, Tehran, Iran

Abstract: A large amount of data can be generated by the Internet of Things (IoT) applications in recent years, this issue may be hard for security, safety, and continuity of production to respond to quickly. Having such a large amount of data places huge demands on the network backbone. By distributing computing services and resources to the edge of the network, edge computing paradigms have recently been proposed to ease core system workloads. In order to design dynamic, adaptable, cost-effective, and dynamic networks, Software-Defined Networks (SDNs) are one of the 5G enabling technologies. Edge computing performs analytical computations on data at the point of data collection (sensors, network switches, etc.) instead of waiting for it to send to the centralized data store in the cloud. SDN technology is used in this paper to provide distributed edge computing through IoT gateways. With SDN, IoT device control and network management could be more effective and efficient. SDN's programmability and flexibility could enable smart management in both traditional IoT environments and heterogeneous smart environments due to the need for real-time data processing. SDN controllers could be distributed and hierarchical. In this research, a review of current research issues, challenges, and further research directions are presented to illustrate how SDN and Edge computing can be implemented efficiently to provide IoT services in the SDN paradigm.

Keywords: Edge Computing, IoT device, Internet of Things, Software Defined Networks.

1. Introduction

In the future, the Internet of Things is expected to connect billions of heterogeneous devices in an intelligent way [1]. Researchers have been attracted to delay-sensitive Internet of Things (IoT) applications for industrial automation, face recognition, and online gaming, due to the popularity of smart devices [2] Managing multiple networks is required for the evolution of the next Internet of Things. Researchers predict that by 2025, objects (like 75 billion devices) will be more interconnected than people. In addition, it should be considered cases such as how to integrate them into separate networks. IoT (or smart environments) also have different communication requirements from current networks with regard to packet size and type, bandwidth demands from different applications, and various levels of fault tolerance and time [3]. IoT requires new technologies to address these problems and to allow a large number of devices to communicate with each other. Technology such as edge computing and Software-Defined Networks (SDNs) is one example of this [4].

SDN is a developing technology that could respond to the current needs of the IoT. Centralized managing optimizes and adjusts the system efficiently and automatically [5]. There is a research gap in solving the problem of integrating IoT with dissimilar networking-based methods, which use the advantages of SDN [6] Edge computing comprises motion support, position awareness, extremely low delay, and positioning close to the user [7]. Among its many applications are industrial automation, virtual reality, real-time traffic control, building automation, and sea-control automation, as well as data analysis. Edge computing is therefore also suitable for data-intensive applications.

Providing the computing continuum to edge-based IoT networks is possible with Software Defined Network (SDN), which eases network management. Despite this, SDN technologies are not well investigated as a way to distribute them to the edge to fit the current network requirements. The purpose of this paper is to provide an overview of the existing solutions used to apply SDN to edge computing, identify the challenges in developing SDN technologies that are well-suited for edge networks, and suggest some options that could be implemented.

https://doi.org/10.46253/jnacs.v5i2.a3

- A unified forwarding plane model separate from the control plane is provided by SDN.
- Control, management, and orchestration can be accomplished with one protocol.
- Dynamic and flexible network infrastructure is the main advantage of using this concept.
- Using SDN on edge nodes can reduce latency and increase scalability.
- Edge computing makes use of SDN to provide a fast, flexible, and reliable computing environment.
- Using the network resources optimally is possible with this combined architecture.
- Edge nodes may be used for fast data transmission to users, and to increase task execution times. It is possible with this combined architecture.
- Edge nodes may be used for fast data transmission to users, and for increasing task execution times.

The rest of the paper is structured as follows: Section 2 describes related work on distributed edge computing in SDN-IoT as well as compares different approaches. Section 3discuss regarding IoT management. Section 4 explains SDN-IoT networks. Section 5 discusses edge computing. Section 6 explains the distributed edge computing and IoT challenges and distributed edge computing and SDN for management are explained in Section 7. Section 7 describes the future directions and section 8 concludes the paper.

2. Related Work

As edge computing becomes more popular, SDN in distributed edge networks is becoming an important topic to investigate. By transforming centralized processing capabilities into distributed architecture, SDN becomes more flexible. In such architecture, processing tasks can be moved from the center of the network to the edge. Recent proposals in this direction include:

SDN-based optimization of cluster replacement (cloud tasks) is proposed in [8]. This algorithm can be adapted to mobile IoT tools via the ranking-based near-optimal placement algorithm (RNOPA). It is proposed that hardware and software switches operate according to unit queuing models in SDN. SDN throughput, delay, and packet loss can be predicted with its analytical capabilities. Existing SDN queuing models focus on analyzing software switches' efficiency [9] A framework for determining and predicting the number of SDN controllers based on the Software Reliability Growth Models (SRGM) model has been proposed that can model the random process of bug emergence. The SRGM framework focuses on various applications for managing SDN-driven networks [10] For fog nodes, a framework is proposed for the IoT structure that uses the edge computation layer. A central controller and OpenFlow distributed switches are used in the SDN system. As well as reducing delay and increasing resource efficiency, the proposed method has a number of advantages [11].In order to address some of these challenges, an SDN-based framework for heterogeneous IoT (SHIoT) is proposed. The system uses a set of options to determine end-user requests and defines an SDN controller to categorize scheduling. The routing mechanism is optimized using the Lagrange relaxation theory [7] A new bulk level mechanism (BLLC) has been proposed in [12]. By categorizing control commands and updating the network from destination to source, the main goal is achieved. Link costs are reduced by 68% and update times are increased by 10% with BLLC. A single-control level is currently used on remote IoT gateways which may cause bottlenecks. The solution to this problem is a hierarchical control framework (master and slave). By reducing the critical delay of IoT control by approximately 30.56%, this method reduces critical delay of IoT control [13] Based on SDIoT software, [14] proposes a traffic-aware QoS routing model in IoT. According to the quality of service required by each packet, a greedy method is proposed that uses Yen's K-shortest paths algorithm to calculate the optimal forward path. IoT services at a large-scale and automated scale can be provided by Muppet (multi-protocol processing at the edge). Mutpet combines the advantages of peer-to-peer and cloud computing. Among other things, it offers cloud-based solutions and super-prototyping automation [15] New software-defined hybrid architectures are proposed in [16] for integration with the IoT. With this architecture, the superstructure of SDN is combined with a real-time scattered system pattern. Traffic services are supported by OpenFlow switches (OF) based on the characteristics of old networks and SDNs. In[2] Monitoring and managing urban mobility with SDN regulators scattered throughout an architecture. A physical SDN regulator divides the IoT system into small clustered networks. Current flow is controlled by MINA as a device and access optimization for various data demands is handled by MINA. The IoT Bridge uses the sensor platform to monitor sensor data and place it on the IoT platform. A safety monitor is then run based on the information gathered by the SDSec regulator. Data is managed and monitored using a standardized device for each end-user [17].

In its early stages, wireless SDN faces numerous problems. The limited resources of low-cost devices require active communication for storage of resources, multiple communications for data collection, and cross-layer optimization to ensure long-term coverage. Even so, the current explanation is not fully incorporated in SDN, and so far, no complete framework and architecture have been developed. There have been outstanding efforts in the area of IoT, source distribution approaches, and initiation systems for SDN-based cellular system management and architecture such as SoftRAN, SoftAir, OpenRoad, and MobileFlow [18]. As evidenced in [19, 20], existing networks are often plagued with issues such as the elaborateness of monitoring protocols and the network between large numbers of smart devices. Using Internet services from different suppliers can be difficult due to these barriers. According to this research, SDN/NFV is not only a key innovation in new technology and services but also a way of measuring IoT's needs through a new model of system structure. Edge computing becomes challenging as data computing grows more complex. In order to lower the computational complexity of cloud-based fog computing,[21]study shows a hybrid architecture of SDN and NFV on an edge node server for IoT devices. The suggested design performs better in terms of reliability and overall time delay (1800 s for 200 IoT devices) (90 percent).In [22] smart healthcare load migration systems with a security compliance structure based on SDN. Patients will be able to get safer, more reasonably priced, and improved medical treatments because of this. In order to achieve this, the usage of SDN-IIoT technology is being investigated for efficient and real-time protection against security assaults. Also, smart healthcare load migration systems with a security compliance structure based on SDN are exploited. Patients will be able to get safer, more reasonably priced, and improved medical treatments because of this. In order to achieve this, the usage of SDN-IIoT technology is being investigated for efficient and real-time protection against security assaults.

2.1 Comparison of Different Methods

Table 1 shows the comparison and evaluation of various methods of recent research in terms of purpose and advantages:

Table.1. *Evaluation and comparison of various methods*

Reference	Method	Year	SDN	Edge computing	IoT	Purpose	Advantage
[21]	Mobile Fog Computing by Using SDN/NFV on 5G Edge Nodes	2022	*	*		Integrating SDN and NFV on an edge node server for IoT devices	Reducing the computational complexity in cloud-based fog computing.
[22]	Intelligent Edge Load Migration in SDN-IIoT for Smart Healthcare	2022	*	*	*	Effective and real-time protection against security attacks	Secure data management is achieved through the proposed framework
[23]	Low-latency edge cooperation caching based on base station cooperation in SDN-based MEC	2022	*	*		Caching techniques for next-generation edge networks were investigated using machine learning techniques	The method can enhance the cache reward and reduce delay.
[24]	Adaptive Computing Optimization for Industrial IoT using SDN with Edge Computing	2022	*	*	*	Computing Optimization for Industrial IoT using SDN	higher throughput, reduced overall delay, and improved success ratio
[17]	Chaotic salp swarm algorithm SD-IoT	2021	*		*	Locating controllers and switches and how to connect them	Reducing network development costs Reducing runtime Enhancing reliability
[25]	Fog Computing Applications in Smart Cities	2020		*	*	Describe the latest developments in smart city fog computing	Investigated data distribution, data security and privacy, and their solutions

[26]	SDIoT-Edge Framework	2020	*	*		*	A survey on complementing IoT services by SDN and Edge Computing is described	The SDIoT-Edge specification sets out the required protection, privacy, integration, and standardization for efficient implementation.
[27]	SDN Enhanced Edge Computing IoT	2019	*	*		*	Discussed the features and capabilities of SDN / NFV and how can these technologies be used effectively. Integration of SDN and EC in IoT.	Provide a reference and standard architecture for developing Edge Computing-based systems and applications.
[28]	SDN Enhanced Edge Computing	2019	*	*			IoT devices and edge servers can be managed and operated more efficiently with SDN and related technologies	In particular, it examined SDN-related network support in more detail. Future challenges and open issues explained for Edge Computing.
[11]	IoT -Fog-based network structure by SDN qualified	2018	*	*			The new framework based on Fog, SDN, and IoT	Reducing delay Enhancing network efficiency
[8]	The ranking-based near-optimal placement algorithm in SDN-IoT	2018	*			*	Locating cloudlets	Reducing the average delay of access and network reliability
[10]	Software Reliability Growth Models (SRGM)	2018	*			*	Determining the number of controllers	Enhancing network reliability and reducing bugs
[7]	SDN-based framework for the Heterogeneous IoT (SHIoT)	2018	*			*	Reducing network complexity	Enhancing network performance
[12]	batch-level update mechanism (BLLC)	2018	*			*	Network update with high security and low cost	Reducing network update cost Increasing security
[14]	Sway: Traffic-Awareness QoS Routing in Software-Well-defined IoT	2018	*			*	Routing in SDN-IoT	Decreasing the delay Reducing the violence of service quality
[15]	Muppet	2018	*	*		*	New edge-based architecture	Scalability Reducing energy consumption Reducing delay
[19]	SDN/NFV - A novel method of organizing System infrastructure for IoT	2018	*			*	Estimating the requirements of the Internet of Things	quality of services, fault tolerance, Continuous performance
[16]	A Hybrid Software well-Defined system Architecture for Next-Generation IoT	2018	*			*	A novel hybrid software-well-defined architecture for compounding with the IoT technology	Self-configuration, self-management Self-compatibility Creating efficient communications for a large number of heterogeneous tools

3. IoT Management

With IoT, billions of heterogeneous devices will be connected intelligently, creating the third generation of the Internet. The massive volume of connected devices has imposed many constraints on the design and structure of the system [12]. Among these challenges are:

- Coverage of wide areas
- Compatibility with heterogeneous devices and multiple communication standards
- Excellent reliability
- Data security and privacy

- Integrating with other communications networks
- The amount of traffic
- Schedule restrictions for some applications

In order to address these problems and provide services to this massive number of devices, we need new technologies to overcome these challenges. Software-defined networks (SDNs) and edge computing are two examples of such technologies[14].

By itself, connecting many objects to the Internet is not sufficient to create an effective IoT network; however, different types of IoT can transform anything from a factory to a smart city [5]. IoT networks of this type require a lot of processing power and communication infrastructure [6]. With SDN, hundreds of thousands of objects can be connected, no matter at what cost or with what kind of network. Understanding these two concepts requires a basic understanding of the four IoT layers:

- Objects (endpoint devices) serve as data sources or operate as sensors in the control and measurement layer.
- The network's physical layer is often used for data backups.
- O&M (operation and maintenance) platform layer
- Application layer to control data analysis

4. SDN-IoT Networks

The development of software-defined networks has been a catalyst for the further development of the IoT. The SDN-IoT controller networks are currently deployed on IoT gateways that are far from IoT facilities. Most of these blockages can be tolerated by the core regulator as a result of monitor delays, link overhead, faults, and hardware complexity [29]. SDN also supports data uploads. Platforms in data centers or IoT platforms interact with the operating software on IoT gateways. SDN facilitates the deployment of IoT platforms by providing North and South bands' connections that support integrated standards for rapid integration [20].

In addition to eliminating the limitations of traditional network architectures, SDN has benefited WAN networks, which aim to adapt networks for rapid changes in industrial and health sectors. WAN controllers abstract the general business model and provide centralized and integrated management of networks. SDN-equipped business networks have been able to integrate domestic applications and daily settings faster with the help of North band interfaces. IoT platforms are more complex than just connecting devices to the network, and they always present various technical and functional issues [30]. The growing number of devices (more than the number of vendors) increases the complexity, difficulty of managing, and vulnerability of networks. Edge computing and SDN have enabled IoT service providers to tackle many of the industry's challenges and complexities [31]. IoT implementations that utilize edge computing and SDN management have the advantage of real-time, secure operation, reliability, and the ability to expand the range of connected objects and the value of the data they produce.

4.1 IoT Management via SDN

With SDN, IoT networks can be virtualized affordably as well as allocated bandwidth and re-adjusted in real time to improve performance and maintain bandwidth. A plug-and-play device configuration allows SDN to provide management of even the most sophisticated networks. The use of SDN can ensure security and provide access control with greater traffic transparency at the edge of the network by detecting and resolving attacks through an automatic application with security rules. A large number of data centers and edge computing devices are managed policy-based by SDNs, thus enabling integrated management of all ICT resources[20]. The features include lifecycle management, control of content, backup files, and virtual machines. Sensors, terminals, communication modules, IoT gateways, and other devices can be managed centrally through the South band controller interfaces. Using plug-and-play technology, it can deploy, authenticate, monitor, and update multiple devices easily. SDNs are expected to support Artificial Intelligence (AI) in the future, as well as deep analysis and automated troubleshooting [8]. Table 2 shows the use of SDN-oriented architecture based on edge nodes.

Table.2. *SDN-oriented architecture based on edge nodes*

Needs	Applications	Solutions
Low delay	Real-time sensors - Remote monitoring	Scattered data processing
Traffic with high speed	Remote monitoring - an integration of teleconnection and data technology in vehicles	Increasing the capacity of IoT - scattered data processing
Traffic with high volume	Remote monitoring – Digital panels	Increasing the capacity of IoT - scattered data processing
Massive communications	Sensors - An integration of teleconnection and data technology in vehicles	Increasing the capacity of IoT - scattered data processing

4.2 The Role of SDN Data Management

By introducing SDN, a pattern that separates data and control planes and creates a dynamic network structure [15]. Data panels are responsible for sending traffic, whereas control panels make decisions about traffic. In SDN, a centralized controller makes decisions about a distributed network. Through an OpenFlow protocol interface, the controller connects to the network devices and communicates with them[19]. As part of all the new systems being developed, the SDN enables the system to be more flexible and scalable. SDN can be used to bridge the gap between edge computing and traditional clouds. The SDN controller can know the length of time that a higher network uses on a particular link, for example, so it can decide whether activities should be uploaded into the cloud or managed by the edge. By passing additional requests to the edge, the controller can prevent bottlenecks in the network and complete the processing[20].

SDN also facilitates the management of applications, including the sharing and distribution of data. Edge computing is especially useful when it is implemented on open platforms that separate network and data connections while supporting third-party applications and edge services. By providing a variety of data platforms and managing delivery, installation, operation, and removal of third-party applications smoothly, SDN supports fast and flexible internal operations. It is the requirement for data management that distinguishes IoT from traditional network management. Current network monitoring applications offer a greater depth of in-service analysis than traditional communication technologies. Data collection, analysis, and uploading are central to IoT, and SDN allows a wide range of different scenarios to be integrated [20].

5. Edge Computing

Computing at the edge is a new method for providing storage, computation, and processing services at a point one or two steps away from the last user [12]. Data, usages, and facilities associated with edge computing are conducted outside cloud servers and at the edge of a system. Providing services close to users can be done using edge-computing systems. There are several edge computing features including high bandwidth, low delay, and the ability to leverage system data for multiple uses[12]. With edge computing, customers and organizations can access new services[2]. In addition to positioning capabilities, improved reality, video analysis, and data storage, edge computing is used [16, 3]. As a result, new edge computing criteria and edge board installations have become essential components for sellers, third parties, and machinists to earn profits. The characteristics of edge computing are similar to those of cloud computing. Several features of edge computing make it unique, including the following:

- Distribution of computing
- Support for mobility
- Situational awareness
- Proximity
- Low latency
- Content awareness
- Heterogeneity

5.1 Advantages of Edge Computing

Cloud computing demonstrates that data management, analysis, control, and processing occur in data centers that host applications and platform layers. Data centers are not optimal for implementing all computational tasks, especially for industrial and health applications that require real-time processing. It was suggested by IoT architects that an open-source platform at the edge of the network could connect, compute, store, and install applications. Platforms that measure and act on events close to objects are part of this edge computing platform. It is generally the case that the edge-computing platform is deployed in an IoT gateway, where most IoT data will be collected shortly. Advantages of the edge-computing platform include[20, 32, 19]:

- Applications requiring fast and real-time performance benefit from Edge computing. On the cloud, response times for control operations can be long; as a result, a number of control and analysis operations need to be performed at the edge of the system to provide immediate responses to specific requests. As an example, production control delays are often less than 10 milliseconds in service control. Automatic guidance must have a few milliseconds of control delays.
- Data collection and acceptance are very convenient with edge computing, as it allows for increased local storage capacity. Furthermore, this approach can be used to measure and control layers containing complex and heterogeneous communication protocols.
- As a result of sending large amounts of IoT data to data centers for processing, the cost of network operations will be unnecessarily inflated. For instance, temperature sensors will only send abnormal data to data centers. A few key features of the image should be sent to the data center instead of the whole image for face detection.
- Computing at the edge is reliable. Processing data in a data center is complex, which increases risk. The edge systems need to be automated in order to increase reliability. To generate control systems, it will be possible to save nodes and the whole system by cooperating with intelligent and automated distribution systems to the edge of the network. If urban data centers fail, the local control feature ensures traffic and pedestrian safety even with a base system such as interconnected traffic lights.
- Secure network access is a very important consideration for many production systems. The network connecting the measuring layer to the data platform layer is extremely vulnerable in IoT. To resolve this problem, securing IoT gateways near the edge of the network is the best option.

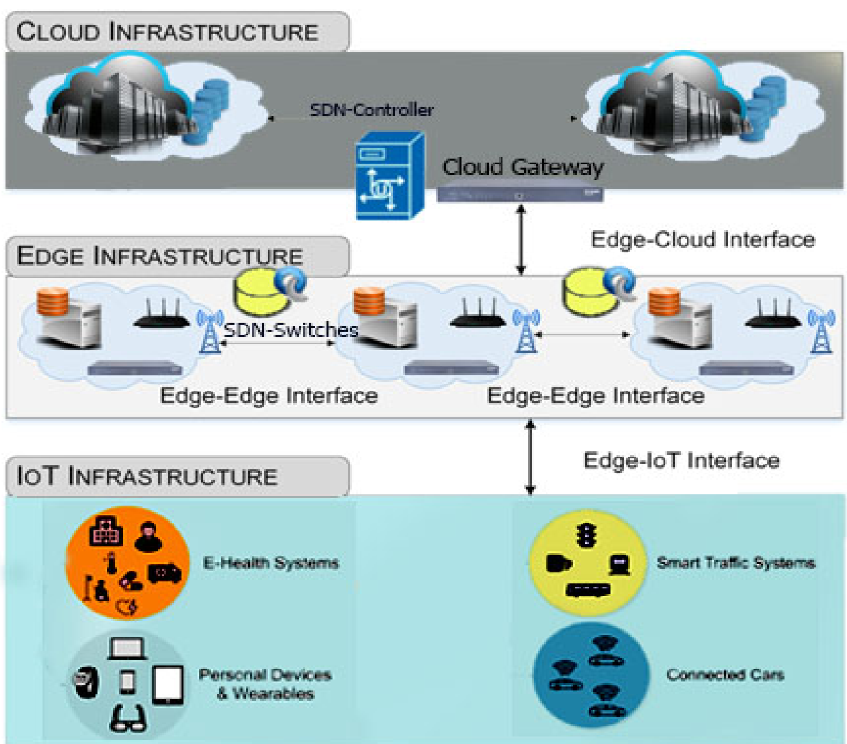


Fig. 1. *An overview of the edge and cloud infrastructure hierarchy.*

Table.3. *Edge computing, SDN, and IoT technologies offer key advantages*

IoT	SDN	Edge Computing
It can access data and information from remote network devices in real time.	Through centralized network provisioning, enterprises can manage and provision their networks more efficiently.	Computing, storage, and network resources are closer to the application, reducing network latency.
Network devices must communicate transparently and efficiently in order to produce faster and more accurate results.	An SDN enables uniform security and policy distribution across the enterprise.	The decentralization of computing and storage resources allows for application scalability.
Automating processes reduces errors, human input, turnaround times, and costs.	It reduces costs by improving server utilization, improving administrative efficiency, and controlling virtualization more efficiently.	Costs are reduced when networks are distributed and require less bandwidth.

In the IoT paradigm, Fig. 1 illustrates the hierarchy of the edge infrastructure. IoT devices use edge cloudlets to communicate with the cloud data center and to offload work to the IoT infrastructure, as illustrated in this figure.

6. Distributed Edge Computing

Real-time applications are created or supported through edge computing systems based on rapid computing capabilities, such as video processing and analytics, self-driving cars, artificial intelligence, robotics, and more. A distributed computing framework called edge computing brings enterprise applications closer to data sources, such as local edge servers or IoT devices. Faster insights, better response times, and greater bandwidth availability can all be delivered by having data close to its source. An architecture that combines SDN and edge computing. Edge computing and traditional clouds can be combined with SDN. An SDN can, for instance, determine whether tasks should be uploaded to the cloud or processed on-premise. Digital transformations are driven by IoT, SDN, and Edge Computing; thus, these three technologies form an influential technology triangle. How these three technologies complement one another is determined by their key advantages as follows (Table 3).

7. IoT Challenges and Distributed Edge Computing and SDN for Management

The Internet of Things (IoT) uses complex networks to control real-world infrastructures using the data produced by millions of sensors. Although IoT devices are capable of performing compute-intensive tasks locally, they are limited by their computational power, including storage, processing, and communication resources. As a result, managing, maintaining, and controlling the IoT is very challenging. For instance, the "Internet Energy" project consists of over 300,000 electrical measuring devices, thousands of IoT gateways, and hundreds of thousands of communication modules. This massive amount of addressable components has proven impossible to control with traditional network management systems. There are many advantages to edge computing that have already been discussed in this paper, however, new requirements have emerged for the network management system[5] Developing a system that manages IoT gateway computations and storage resources and implements open third-party applications for the gateways is now necessary. For example, for high-density traffic processing, big quantities of processing relations, maximum traffic processing, and processing with low latency, the solution that addresses the new requirements of IoT is to allocate the processing of the IoT analytics produced by the core DC to micro-DCs and small-DCs at the system edge (edge computing), also known as edge IoT analytics.

Data or outcomes can be analyzed initially using cloud-edge technologies, and only the necessary data or outcomes are sent for further analysis (e.g. huge amounts of data) or kept in the central storage database. A scalable model is created by analytically distributing IoT, network, and storage databases. So, lightweight computing sources at different network locations are needed. This means that the edge computing nodes were recognized as fog nodes as well, which can reduce network delay, bandwidth consumption, and bulk data transfer by processing network data. The spread of IoT and the use of system sources require close synchronicity between IoT analysis platforms, SDN platforms, and cloud substructures [10] Due to the uncontrollable path, routing between two devices is not possible in the context of IoT. Thus, conventional data transfer approaches aren't suitable for IoT. However, some studies reflect on compatibility and performance optimization for wireless networks, but these approaches do not address issues such as the huge need for data communications, characteristics of the industrial network, and network topology. Data transfer from IoT devices raises new challenges. Among them are:

- To deal with the enormous amount of data at dissimilar levels between devices, a new architectural framework is needed since the current framework of the network faces challenges.
- The existing unified routing procedures or cluster-based IoT diffusion approaches do not adequately address the varying delays in industrial IoT and the need for fast Internet-based decision-making. Therefore, a new architecture, like SDN and EC, should be used to suggest improved data transfer methods.
- The imbalance of power usage along with the traffic in the support-using nodes has not been fully resolved.

8. Future Research Directions

Future research needs to resolve numerous critical issues related to SDN, Edge computing, and IoT despite these technologies' potential. The following cases should be taken into consideration in future direction work:

- The quality of service in IoT networks can be significantly improved through improvements in several performance metrics, such as reducing energy consumption and response time compared to traditional approaches.
- Optimizing decision-making and ensuring better load distribution between edges in SDN-IoT networks.
- It will require a thorough review to standardize Edge Computing, SDN, and IoT because of the differences in infrastructure.
- There is an exponentially growing challenge in IoT to guarantee QoE in the face of traffic explosion.
- Various data offloading mechanisms and flow classification can be used in SDN-IoT networks.

There are many opportunities and challenges in this area.

9. Conclusion

The computational power of IoT devices, including storage, processing, and communication resources, is limited. By bringing computation closer to IoT devices' edges, edge computing resolves resource limitations. Hence, edge computing offers low-cost computation solutions. Even though SDN wasn't specifically designed to address IoT challenges, it can help in solving complex problems and orchestrating IoT services efficiently. SDNs and IoT networks are two major developments in the network area. By utilizing SDN capabilities, Internet-connected devices will be more secure, controllable, and manageable. SDN will improve the security of the network against data attacks, according to experts. With SDN technology, companies can build very large networks and manage them easily using standard equipment. Big data infrastructure can be built with SDN technologies. SDN appears to meet the needs of big data processing software by integrating agility, multiple domains, and centralized management.Edge computing and the Internet of Things indeed offer many benefits for utilizing live data in many systems, but manual management of the edge-based network will become increasingly ineffective as it grows incrementally. Security, safety, and continuity of production often require quick responses to the explosion of data being collected and transmitted through IoT networks. Many IoT applications rely on edge computing to operate. As a result, designing edge computing architectures, establishing open standards, and accelerating the adoption of IoT ecosystems require more research and better solutions.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

[1] R. Munoz, R. Vilalta, N. Yoshikane, R. Casellas, R. Martınez, T. Tsuritani, and I. Morita, "Integration of IoT, Transport SDN, and Edge/Cloud Computing for Dynamic Distribution of IoT Analytics and Efficient Use of Network Resources," JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. 36, no. 7, pp. 1420-1429, 2018.

[2] D. Wu, D .I.Arkhipov, E .Asmare, Z .Qin, and J .A.McCann, "UbiFlow: Mobility management in urban-scale software defined Iot," in IEEE Conference on Computer Communications, 2015.

[3] S. J. Shackelford, "Governing the Internet of Things," The Internet of Things, 2020.

[4] S. Tayyaba, N. S. Afzal Khan, W. Naeem, "Software-Defined Networks (SDNs) and Internet of Things (IoTs): A Qualitative Prediction for 2020," (IJACSA) International Journal of Advanced Computer Science and Applications, vol. 7, no. 12, pp. 385-404, 2016.

[5] S. Jazaeri, R. Berangi, "Survey present and future visions of Internet of Things (IoT)," Science Journal-Researcher, vol. 8, no. 7, pp. 8-14, 2016.

[6] S. Jazaeri, R. Berangi, "Study the Challenges of Using and Development of 5G Networks," Science Journal- Report and Opinion, vol. 8, no. 7, pp. 13-19, 2016.

[7] H. Tran, D. Tran, L. Nguyen, Q. Ha and V. Tong, "SHIOT: A Novel SDN-based Framework for the Heterogeneous Internet of Things," Informatica, vol. 42, pp. 313-323, 2018.

[8] L. Zhao, W. Sun, Y. Shi, J. Liu, "Optimal Placement of Cloudlets for Access Delay Minimization in SDN-based Internet of Things Networks," IEEE internet of things, pp. 1-12, 2018.

[9] D. Singh , B. Ng, Y. Lai , Y. Lin , W. K.G. Seah, "Modelling Software-Defined Networking: Software and hardware switches," Journal of Network and Computer Applications, vol. 122, p. 24–36, 2018.

[10] P. Vizarreta, K. Trivedi, B. Helvik, P. Heegaard, A. Blenk, W. Kellerer, and C. M. Machuca, "Assessing the Maturity of SDN Controllers withSoftware Reliability Growth Models," IEEE Transactions on Network and Service Management, pp. 1-15, 2018.

[11] A. Khakimov, A. A. Ateya, A. Muthanna, I. Gudkova, E. Markova, and A. Koucheryavy, "IoT-Fog based system structure with SDN enabled," in Proceedings of ACM Woodstock conference, Amman, Jordan, 2018.

[12] W. Ren, Y. Sun, H. Luo and M. Guizani Fellow, "BLLC: A Batch-level Update Mechanism with Low Cost for SDN-IoT Networks," IEEE Internet of Things Journal, pp. 1-13, 2018.

[13] W. Ren, Y. Sun, H. Luo and M. Guizani, "A Novel Control Plane Optimization Strategy for Important Nodes in SDN-IoT Networks," IEEE Internet of Things Journal, pp. 1-14, 2018.

[14] N. Saha, S. Bera,E, S. Misra, "Sway: Traffic-Aware QoS Routing in Software-Defined IoT," IEEE Transactions on Emerging Topics in Computing, pp. 1-12, 2018.

[15] M. Uddin, S. Mukherjee, H. Chang, and T.V. Lakshman, "SDN-based Multi-Protocol Edge Switching for IoT Service Automation," IEEE Journal on Selected Areas in Communications, pp. 1-11, 2018.

[16] A. Lee, X. Wang, H. Nguyen and I. Ra, "A Hybrid Software Defined Networking Architecture for Next-Generation IoTs," Ksii transactions on internet and information systems, vol. 12, no. 2, pp. 932-945, 2018.

[17] S. Krishnamoorthy and K. Narayanaswamy, "SDN Controller Allocation and Assignment Based on Multicriterion Chaotic Salp Swarm Algorithm," Intelligent Automation & Soft Computing, 2021.

[18] J. Costa-Requena, J. Llorente Santos, V. Ferrer Guasch , K. Ahokas, G.Prem sankar, S. Luukkainen, I. Ahmad, M. Liyanage, M. Ylianttila, O. Lopez Pe fez, "SDN and NFV integration in generalized mobile network architecture," in Net¬works and Communications (EuCNC), 2015 European Conference, Paris, France, 2015.

[19] D. Sinh, L. Le, B. Paul Lin, L. Tung, "SDN/NFV - A new approach of deploying network infrastructure for IoT," in The 27th Wireless and Optical Communications Conference (WOCC2018), 2018.

[20] S. S.Jazaeri, S. Jabbehdari, P .Asghari and H. H Seyyed Jazvadi, "Edge computing in SDN-IoT networks: a systematic review of issues, challenges and solutions," Cluster Computing, vol. 2, pp. https://doi.org/10.1007/s10586-021-03311-6, 2021.

[21] G. R. Sreekanth, S. Ahmed Najat Ahmed, M. Sarac, I. Strumberger, N. Bacanin, and M. Zivkovic,, "Mobile Fog Computing by Using SDN/NFV on 5G Edge Nodes," Computer Systems Science and Engineering, vol. 41, no. 2, p. 751–765, 2022.

[22] H. Babbar, S. Rani and S. A. Alqahtani,, "Intelligent Edge Load Migration in SDN-IIoT for Smart Healthcare," IEEE Transactions on Industrial Informatics, 2022.

[23] C. Li, C. Qianqian, & Y. Luo, , "Low-latency edge cooperation caching based on base station cooperation in SDN based MEC," Expert Systems with Applications, vol. 191, 2022.

[24] S. Chandramohan, M. Senthilkumaran and M. Sivakumar, "Adaptive Computing Optimization for Industrial IoT using SDN with Edge Computing," in 6th International Conference on Computing Methodologies and Communication (ICCMC), 2022.

[25] G. Javadzadeh, A. M.Rahmani,, "Fog Computing Applications in Smart Cities: A Systematic Survey," Wireless Networks, p. 1433–1457, 2020.

[26] W. Rafique, L. Qi, I.Yaqoob, M. Imran, R. Rasool, & W. Dou, "Complementing IoT Services through Software Defined Networking and Edge Computing: A Comprehensive Survey," IEEE Communications Surveys & Tutorials, vol. 22, no. 3, pp. 1-45, 2020.

[27] R. S.Alonso, I. Sitton-Candanedo, S. Rodrıguez-Gonz´alez, O. Garc´ıa, and J. Prieto, "SDN Enhanced Edge Computing," Springer Nature Switzerland AG, pp. 289-301, 2019.

[28] A. Wang, Z. Zha, Y. Guo, & S. Chen, "Software-Defined Networking Enhanced Edge Computing:A Network-Centric Survey," IEEE, vol. 107, no. 8, p. 1500–1519, 2019.

[29] W. Zada Khan, E. Ahmed, S. Hakak, I. Yaqoob, A. Ahmed, "Edge computing: A survey," Future Generation Computer Systems, pp. 1-45, 2019.

[30] B. B. Gupta Megha Quamara, "An overview of Internet of Things (IoT): Architectural aspects, challenges, and protocols," Concurrency Computat Pract Exper., pp. 1-24, 2018.

[31] Y. Mao, C. You, J. Zhang, et al., "A survey on mobile edge computing: the communication perspective," IEEE Commun. Surv. Tutor., vol. 99, pp. 1-37, 2017.

[32] Y. Jararweh, M. Al-Ayyoub, A. Darabseh, E. Benkhelifa, M.Vouk, and A. Rindos, "SDIoT: a software defined based internet of things framework," J. Ambient Intell. Humaniz. Comput., vol. 6, no. 4, pp. 453-461, 2015.