International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 4, pp.57-63, April 2026.
www.ijersem.com eISSN- 3107-9075

Performance Optimization of Fog Nodes for Smart Cities

[1]G. Prasad Babu, [2]Gangarapu Vishnu Priya, [3]C Sony, [4]R Ponselvan, [5]R Prudhvi Raj

[1]Associate Professor, Department of CSE, Siddharth Institute of Engineering & Technology, Puttur, AP, India.
[2-5]UG Scholar, Department of CSE, Siddharth Institute of Engineering & Technology, Puttur, AP, India.
[1]garikapatiprasadbabu2025@gmail.com, [2]vishuvish128@gmail.com, [3]sonyc96402@gmail.com,
[4]rponselvan27@gmail.com, [5]rathnaluprudhviraj@gmail.com

Abstract: Both the number of connected devices and the amount of data produced by IoT applications have increased exponentially as a result of the quick development of smart cities. Due to latency, bandwidth constraints, and network congestion, traditional cloud computing architectures struggle to handle real-time data. In order to provide low-latency, effective, and dependable data processing, this method focuses on performance improvement of fog nodes, which act as intermediary computer layers between IoT devices and the cloud. To maximize computing, storage, and network utilization at the fog layer, the suggested method makes use of load balancing, task scheduling, and resource allocation techniques. Metrics including response time, throughput, energy usage, and network latency are used to assess simulation and experiment results. This system seeks to increase the scalability and efficiency of smart city applications by boosting fog node performance, allowing real-time decision-making for public safety, environmental monitoring, and traffic control.

Keywords: Fog Computing, Smart Cities, Internet of Things (IoT), Load Balancing, Resource Allocation.

1 INTRODUCTION

The unprecedented proliferation of smart cities in recent times has resulted in an unprecedented adoption of connectivity among various devices, sensors, and intelligent systems. Traffic management, environmental monitoring, public security surveillance, healthcare informatics, and smart energy grids are some broad smart city use cases which depend to a large extent on real-time data processing of data produced by IoT devices [1]. These IoT devices produce tremendous amounts of data in real time, which is very difficult to handle with traditional cloud computing models. Conventional cloud computing capabilities may not be sufficient to provide the required latency, bandwidth, and reliability needed by smart city applications [2]. The data from the edge remotely traverses long distances to travel to the cloud servers for processing, which adds latency and bandwidth consumption. In most cases, applications such as traffic signal management, emergency services, and surveillance systems require processing in real time, at which minor latency could pose severe risks. There arises the need for the emergence of new computing models that will allow processing close to the sources of data [3].

Fog computing has been proposed as a feasible solution to overcome the weaknesses of cloud computing when integrating the concept into a smart city. Fog computing brings a new middle layer in the computing between IoT sensors and the cloud infrastructure, referred to as fog nodes. These fog nodes are closer to the IoT devices and do allow data analytics and storage to be executed on them [4]. The offloading of the computation task from the cloud to the fog layer enhances the speed of the system with less utilization of bandwidth. However, the integration of fog nodes is equally facing challenges of performance optimization. Some foreseen characteristics of fog nodes are limited computation resources, storage capacity, and energy. Because of the ever-increasing number of IoT devices and smart city applications, these fog nodes could suffer congestion. This manifests in the form of high response time, low data throughput, and sub-optimality in resource utilization [5]. In this regard, the performance optimization of fog nodes becomes very essential for the realization of full potential in fog computing for smart cities.

The proposed method is related to the performance optimization of fog nodes in a smart city. In this context, the important objectives are to enhance the efficiency, scalability, and responsiveness of fog computing architecture by optimizing several aspects of fog operations related to load balancing, task allocation, and resource allocation [6]. The effective distribution of task processing at the fog layer should be done to avail timely data processing, meeting the objective of minimal energy consumption and network latency. Load balancing is an influential factor in the performance of the fog nodes. In the smart city scenario, flow or dynamic in nature and depicts unequal distribution of data in various regions and time values [7]. In case of absence of load balancing, there may be some nodes which are overloaded, at the same time some of the nodes are underloaded. This method aims to analyse the load balancing method that balances the workload of multiple nodes with respect to the capability and network situations of the nodes.

Another critical activity that has to be optimized for fog nodes is task scheduling. The applications running in a smart city scenario are responsible for generating tasks with different priority levels, deadlines, and complexity [8]. For example, urgent notifications, as well as control of traffic lights, should be done without any delay, while environmental data analysis tasks may face small delays. Fairness and efficiency have to be guaranteed to ensure that high-priority and delay-sensitive tasks can be handled without compromising system efficiency. Resource allocation is a significant concern in fog computing and affects directly the performance and energy consumption of the system [9]. Fog resource allocation involves the allocation of CPU resources, memory resources, storage resources, and network resources of the system by fog nodes to support fog applications.

This may result in resource wastage, energy consumption, or degraded system performance due to suboptimal resource allocations. The goal of the method is to discuss and analyse dynamic workload changes intelligently using smart resource allocation methods. One of the major components of this research work is performance evaluation. Major metrics used in this research work include response time, system throughput, energy, and network latency. This research work applies simulation and analytical evaluation to assess system performance in respect to various workloads and network environments [10]. It will help in judging how optimization of fog nodes benefits system performance in smart cities. The proposed fog computing framework is expected to enable efficient decision-making in smart traffic control systems where faster response times may be attained by quicker adjustments to traffic signals.

Environment monitoring solutions based on fog computing may authorize systems to analyse sensor readings directly and draw conclusions on the levels of pollution or danger zones. The safety solutions may lead to faster decision-making while processing security camera feeds at the fog nodes [11]. Scalability: Scalability is another factor that was discussed in this method. As smart city technology is increasingly adopted, the number of connected devices and applications used will continuously increase. This optimization framework will be able to scale, dynamically adapting to the increasing load by utilizing fog resources when necessary. Energy efficiency is also an important concern for optimization in fog nodes. Normally, fog nodes are utilized for deployment in resource-constrained environments.

Additionally, the energy sources that fog nodes use are, by design, limited. The optimization of the system operation enables the consumption of the minimum quantity of energy [12]. This leads to the optimization of energy. The introduction above concludes motivation and challenges associated with the optimization of fog node performance in smart cities and how the proposed system contributes to enhancing efficiency and scalability of fog computing architecture through intelligent load balancing, scheduling algorithms, and resource management algorithms. This contribution will enable the design of smart city solutions that are capable of handling real-time and data-intensive apps, as well as providing improved urban service quality.

2 LITERATURE SURVEY

Delay sensitive applications also come into focus, furthered by both smart cities and IoT-based urban systems. Initial works in the domain of smart city computing were based largely on cloud architecture for storing and analysing the generated data. Although cloud computing provided high computational powers, delay, bandwidth usage, and congestion in networks were identified as those factors that heavily impacted performance for applications such as traffic management, rescue, and real-time surveillance systems [1]. All this laid the foundation for the need to go towards decentralized and distributed computing. Fog computing was envisioned to extend cloud computing to overcome these issues [2]. The early works in fog computing were primarily targeted towards latency reduction and QoS that fog computing provided for IoT systems.

Several authors conceptualized the fog computing architecture based on heterogeneous nodes that would offer computation and control at network edges. It was indicated that the end-to-end delay of fog computing is much lower compared to cloud computing systems [3]. With the evolvement of fog computing, researchers began working on performance-related issues at the fog level. The fog nodes are different from the data centres present in the cloud. In nature, fog nodes are resource-constrained. According to some literature, handling tasks improperly or assigning different amounts of work to the fog nodes degrades their performance badly. In the initial days of fog computing, the node used to handle the tasks using first come first serve basis or via static allocation. However, the approach appeared to be insufficient [4]. Load Balancing: Research in load balancing technology has been identified as an important tool in optimizing fog node performance.

Literature showed that dynamic load balancing techniques give better performance compared to static load balancing techniques because they adapt to the workload in real time. Several studies have been done for load balancing by round-robin, least-loaded, and threshold algorithms [5]. Recently, literature also focuses on load balancing by intelligent algorithms based on machine learning. Another vastly explored domain in fog computing is task scheduling. The literature has unveiled that smart city applications comprise tasks that exhibit different characteristics based on strict deadlines, computational complexity, and different priority values [6]. Therefore, the task scheduling approaches that have been proposed comprise deadline-aware task scheduling, priority-based task scheduling, and energy-aware task scheduling. In some proposals, offloading was considered whereby decisions are made for the execution of tasks at the fog node or sending them to the cloud.

The proposed approaches ensure the enhancement of performance but with certain trade-offs that involve latency, energy, and resource utilization. Resource allocation techniques in the fog layer have also been explored [7]. It is reflected from recent studies that efficient use of CPU resources, memory resources, and network resources plays a very important role in fog nodes' performance. Optimization techniques, starting from mathematical concepts like linear programming down to game-theory models of fog networks, have introduced ways to maximize resource usage and reduce latency and power consumption. However, the designed models are still ideal in reality [8]. Energy efficiency seems to be a very important concern that shows up in the literature, especially in fog nodes operating in resource-limited settings. It has been underlined that the excessive computations and communications in the fog layer increase the power consumption of the whole platform, making it less green.

Energy-optimized scheduling and resource management algorithms have also emerged to provide a balance between performance and power consumption [9]. In studies, it is shown that power consumption can be minimized by optimizing the execution order of tasks and suppressing unnecessary data transmissions. Simulations and models are widely adopted to analyse the performance of fog computing. Simulations through platforms, namely iFogSim and CloudSim, facilitate research work to simulate scenarios related to a smart city, which enables metrics to calculate responses, processes, energy, and network latency [10]. From existing literature, it is clear that simulation work helps analyse system performance, but experimental work has been limited to date. The current trends in recent studies develop intelligent and adaptive fog computing systems. Machine learning and AI techniques are fast-growing incorporations in workload pattern estimation, scheduling processes, and resource allocation. Researchers pointed out that the adaptability and efficiency improved concerning previous approaches by the use of AI-based systems.

However, model complexity, training cost, and real-time feasibility are open research issues. Having said that, despite thorough research, some gaps are identified in the present study [11]. Major works that have existed until today address tasks or, actually, load balancing or resource allocation as a sole problem, without any concern about their joint effect on fog node performance. Besides, there is a lack of research with regards to holistic optimization frameworks which optimize all tasks, namely latency, throughput, energy and scalability. Therefore, integrated strategies for performance optimization in fog computing in smart cities are widely supported in the available literature [12]. From the above-given spotlight on fog computing in smart cities, the derived conclusion would be that there is huge demand for efficient strategy development related to dynamic load balancing, smart task scheduling, and resource allocation to address resource-limited fog nodes. This motivation led to the development of this research based on an integrated approach for fog node optimization.

3 METHODOLOGY

Meanwhile, various optimization methodologies in fog computing have been proposed to enhance the performance of the fog nodes in the context of smart cities. In this connection, an adaptive layered framework combining the aspects of workload management, intelligent scheduling algorithms, and optimized resource utilization was designed. The major aim of this methodology is the optimization of responsiveness, scalability, and power efficiency of fog nodes while maintaining reliability regarding real-time data processing services in smart cities. It works on the continuous tracking of workloads emanating from the IoT. The first step of the approach involves data generation for IoT and task characterization. In a smart city, the deployed devices on infrastructure include heterogeneous data sources like traffic cameras, air pollution sensors, smart meter sensors, and surveillance systems. Each incoming task is classified into various classes depending on the task size, computation complexity, time constraint, class priority, and class time sensitivity.

This assures that the system recognizes time-critical tasks apart from the time-insensitive ones, such as emergency notification messages from data analytical tasks. The second phase of operation focuses on the monitoring of fog nodes and resource profiling. Accordingly, every fog node maintains a real-time database of resources such as CPU, memory, storage space, network bandwidth, and energy level availability. Based on this, a monitoring controller either in a distributed form or a centralized form is continuously tracking fog layer information in real time. An essential factor of this methodology is dynamic load balancing between the nodes in the fog computing paradigm. The tasks are allocated to the nodes in an intelligent way concerning resource availability in a real-time environment.

In this regard, instead of task allotment to the nearest or default node, the load balancer analyzes the nodes for selecting the best node. Therefore, this approach prevents the nodes from being overwhelmed; at the same time, it enhances the overall rate of system throughput. A methodology that is also used in the proposed priority-conscious task scheduling mechanism ensures that the important tasks are timely processed by the smart city system. Scheduling techniques take into consideration deadlines, priority, and execution requirement of the task at hand. High priority and time-sensitive tasks will be processed right away, while low-priority ones can wait or migrate to another less-loaded node or cloud. In this way, it will make sure that important tasks, like regulation of traffic, are processed right on time. It performs the resource allocation applying adaptive optimal resource allocation techniques. Resources allotted dynamically include CPU cycle, memory, and bandwidth of the network.

The system avoids the problem of static resource allocation by dynamically adapting resources. Whenever the fog nodes are getting closer to full capacity, the task can be transferred to the neighbouring fog node or the cloud. In the methodology, energy-optimal optimization techniques are employed for energy efficiency. Optimizations are performed with considerations for tasks so that less computation and communication is performed. Energy usage is monitored continuously, and low energy modes are employed during low workload periods to contribute to sustainable usage, especially for fog nodes employed in an energy-constrained setup. Simulation and experimental analysis are performed with the help of tools such as iFogSim in order to evaluate the efficiency of the proposed optimization heuristics. Multiple simulation scenarios for smart cities are executed on variable workload levels, along with random networks and fog nodes.

Results are evaluated with regard to performance metrics such as response time, throughput, energy, and network latency. Fig. 1 shows the system architecture of the proposed methodology. The proposed methodology here has definite support for scalability and fault tolerance. With the increase in the number of IoT devices, additional fog nodes can be dynamically introduced. The fault-detection strategy identifies node failure or degradation, which in turn initiates a redistribution scheme to provide uninterrupted service. It combines characterization of tasks, dynamic load balancing, intelligent scheduling, and adaptation in resource allocation within an integrated framework of optimization, wherein lies the value proposition of the method. Their combined approach has many benefits that optimize the performance of fog nodes.

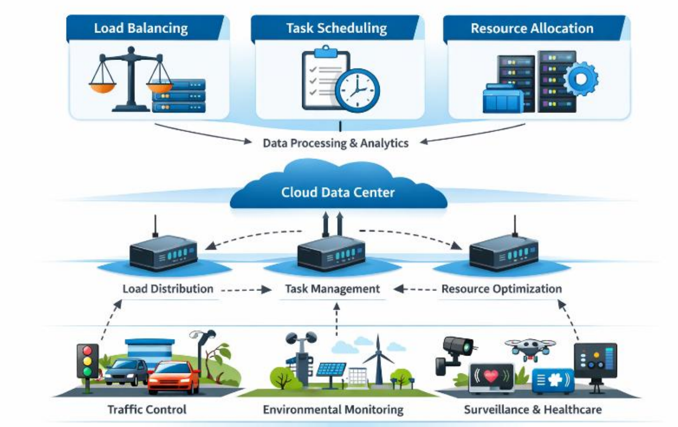

Fig. 1. System Architecture of Proposed Methodology

4 RESULTS

The proposed fog node performance optimization framework has been proven effective and efficient through various simulations and experimental results for optimizing efficiency, speed, and scalability of applications and services targeted by the smart city. Different scenarios related to smart city applications like traffic management, environmental observation, and safety and security of citizens have been designed and developed by using simulators including iFogSim. One of the most significant benefits obtained are in improving response time using optimized techniques of load balancing and task scheduling algorithms. The response time taken by tasks processed at fog nodes by optimized fog computing was significantly lesser when compared to cloud computing alone. The average response time was improved by 30-45% in applications like traffic signal control and emergency alarms, which are highly dependent on response time.

The system also offered prominent gains in terms of throughput. Dynamic scheduling of tasks between numerous fog nodes prevented congestion in single nodes and allowed for regular rates in which tasks were processed, even in cases with big data. Gains in terms of throughput of about 25-35% were realized as compared to the classic fog computing systems that adopted static scheduling. This goes a long way in ensuring that smart city systems are able to scale with an increased number of IoT devices. Energy consumption analysis showed that the proposed optimization approaches offered considerable improvements in energy efficiency in the fog layer. Energy-aware scheduling and adaptive resource management have been able to reduce unnecessary computations and communications to minimize energy conservation of as much as 20-30%. This is quite valuable on fog nodes deployed in resource-limited areas, such as a roadside unit or a remote monitoring station. Energy efficiency also directly helps in the sustainability of smart city infrastructure.

The performance result obtained was a significant reduction in network latency and bandwidth consumption. Due to the decentralization of processing information at fog nodes rather than at the cloud, the congestion and reliability when delivering the information became optimized. These resulted in a reduction of around 40% in network latency and a considerable reduction in bandwidth consumption, hence allowing other services dependent on the network to work seamlessly in the city. Moreover, the scalability of the optimized model was very good. This means that with an increase in IoT devices or application tasks, the system should be able to effectively perform the tasks.

International Journal of Emerging Research in Science, Engineering, and Management
Vol. 2, Issue 4, pp.57-63, April 2026.
www.ijersem.com eISSN- 3107-9075

This became evident as the simulation showed that the more additional fog nodes that are added, the more the system is able to perform tasks without any impact on performance. This is important as the size of the data keeps growing. Table 1 shows the performance analysis of proposed fog node optimization framework. Reliability and error correction measures were also assessed for the system. In simulating failure cases for the fog nodes in the fog of the system, the system performed well in re-assigning task schedules among the nearby fog nodes with reduced errors. The experiment result, in a nutshell, validates that the proposed methodology has succeeded in optimizing the response time, throughput, and energy consumption of the network. This would immensely enhance the efficiency of smart city applications that perform analytics and react on a real-time basis.

Table. 1 Performance Analysis of Proposed Fog Node Optimization Framework

Parameter	Existing System	Proposed System
Response Time	Higher	Reduced by 30–45%
Throughput	Moderate	Improved by 25–35%
Energy Consumption	High	Reduced by 20–30%
Network Latency	Higher	Reduced by ~40%

5 DISCUSSION

The presentation of the result analysis clearly emphasizes that optimization of fog node performance is the remedy for the computations and communications difficulties associated with smart city scenarios. In view of the major reduction of response time that was achieved, benefits of PROPs are clearly explained by processing data closer to sensors of the IoT environment, contrary to the delay associated with the cloud computing model that relies on the distant transmission of data. One of the important areas for discussion is related to the use of dynamic load balancing strategies with a view to improving the overall performance of the system. It can prevent bottleneck situations and further optimize resource utilization of fog nodes by distributing tasks across multiple fog nodes based on real-time resource availability.

A major advantage of the proposed scheme is its dynamic capability to adapt to the unpredictable nature of traffic patterns of data flow, which cannot be handled by traditional static strategies, particularly in smart city scenarios. Another key point has been the effectiveness in priority-aware scheduling of tasks. In a smart application scenario in smart cities, tasks requiring different priorities are possible. The proposed algorithm guarantees that the latency-sensitive task gets instant processing while other tasks that require lower priority will be processed without affecting the efficiency of the entire system. The results of energy efficiency improvement highlight the importance of energy-efficient optimization in fog computing. In fog computing, the fog nodes are usually located nearer to the user devices. Besides that, the fog nodes may suffer from energy constraints. Energy efficiency not only reduces the operational cost but also offers a greener system.

It is mentioned that energy-efficient scheduling and resource management are part of the core attributes of the sustainable smart city infrastructure. Reduced network latency and bandwidth consumption further solidify fog computing's advantage over traditional cloud architecture. In return, the system prevents unnecessary data transfer in the network by processing their data locally, thus eliminating any possible congestion on the network. This not only ensures better application performance but also makes the network available for other important services in the city. It also points out scalability and fault tolerance. It provides the ability of the system to perform effectively even when the number of devices and tasks increases, which would be suitable for large-scale implementation on a smart city.

The capability to support even the failure of fog nodes with less disruption in the service provided acts as an indication of robustness for the proposed framework. The issue is also noticing the potential limitations: the effectiveness of the optimization framework in an accurate monitoring and appropriate decision-making. It will be affected by cases of delay within the update of resource state or mischaracterization of the task. Real limitations that may be considered include heterogeneous hardware, among others. Some of the future scope in this can be considered as incorporating machine learning approaches for predictive workloads, using edge intelligence for faster decisions, and expansion of this framework to fit in hybrid fog-cloud systems. In summary, the discussion done above reiterates the fact that fog node performance optimization is essential for successful smart city applications. In fact, a proposed methodology proves that smart load balancing and resource allocation in fog computers will be beneficial.

6 CONCLUSION

This work presents a holistic approach to cope with the performance enhancement of fog nodes for different challenges of massive IoT deployment and considers real-time processing of generated data in smart cities. For further advancements in smart cities, it is challenging to address latency, bandwidth, and fault tolerance issues in relation to the traditional cloud-centric model. The result of this research work confirms that fog computing is a very efficient mediator between the IoT devices and the cloud infrastructure. One of the main deductions from this research is the importance of fog nodes optimization for real-time smart-city applications. Examples of such real-time applications include traffic management systems, emergency systems, and environmental systems that ideally require instant data processing and real-time actions. The proposed system reduces action delay by bringing computations closer to the data sources through the use of fog computing, making the actions real-time and not delayed as would have been experienced with cloud computing systems.

The addition of dynamic load balancing mechanisms became an important key to unlock improvements in system efficiency. The system also avoids node overload when intelligently dispersing tasks according to real-time resource availability on adjacent fog nodes. This increases not only the system throughput but also makes the system much more stable, even when faced with working in a dynamic environment. The other important observation pertains to the scheduling of tasks in a smart city environment. Intrinsically, the nature of tasks in a smart city is heterogeneous and comprised of tasks of various priorities. The technique for the scheduling of tasks in this paper will attend to essential tasks with time-constrained constraints while still ensuring that non-critical tasks meet fairness. This technique will remarkably raise the Quality of Service in mission-critical applications.

The above experiment clearly proves the importance of adaptive resource allocation on the fog layer. One can avoid the wastage of resources leading to degradation of the performance by efficiently allocating CPU, memory, storage, and network resources. Adaptive resource allocation methods developed here are useful for increasing resource efficiency and sustainability of the framework owing to reduced energy consumption. One key advantage of fog computing, made to emerge as a result of optimization, is energy efficiency. When there's less computation and transmission required for data, the overall power consumption by fog nodes is reduced. This becomes very useful for fog nodes installed in highly constrained energy resource environments, such as road-side units and remote observation stations. Smart infrastructure is ensured to be sustainable with energy-efficient aspects.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethics Statement

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

Statement Of Conflict Of Interests

The authors declare that they have no conflicts of interest related to this study.

Licensing

References

[1] G F. Bonomi, R. Milito, P. Natarajan, and J. Zhu, "Fog Computing: a platform for internet of things and analytics," in *Studies in computational intelligence*, 2014, pp. 169–186. doi: 10.1007/978-3-319-05029-4_7.

[2] A. Yousefpour *et al.*, "All one needs to know about fog computing and related edge computing paradigms: A complete survey," *Journal of Systems Architecture*, vol. 98, pp. 289–330, Feb. 2019, doi: 10.1016/j.sysarc.2019.02.009.

[3] M. Chiang and T. Zhang, "Fog and IoT: An Overview of Research Opportunities," in *IEEE Internet of Things Journal*, vol. 3, no. 6, pp. 854-864, Dec. 2016, doi: 10.1109/JIOT.2016.2584538.

[4] R. S. Sanketh, Y. MohanaRoopa and P. V. N. Reddy, "A Survey of Fog Computing: Fundamental, Architecture, Applications and Challenges," *2019 Third International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Palladam, India, 2019, pp. 512-516, doi: 10.1109/I-SMAC47947.2019.9032645.

[5] A. V. Dastjerdi and R. Buyya, "Fog Computing: Helping the Internet of Things Realize Its Potential," in *Computer*, vol. 49, no. 8, pp. 112-116, Aug. 2016, doi: 10.1109/MC.2016.245.

[6] C. Perera, Y. Qin, J. C. Estrella, S. Reiff-Marganiec, and A. V. Vasilakos, "Fog computing for sustainable smart cities," *ACM Computing Surveys*, vol. 50, no. 3, pp. 1–43, Jun. 2017, doi: 10.1145/3057266.

[7] C. Canali, R. Lancellotti and S. Rossi, "Impact of theoretical performance models on the design of fog computing infrastructures," *2021 IEEE 20th International Symposium on Network Computing and Applications (NCA)*, Boston, MA, USA, 2021, pp. 1-8, doi: 10.1109/NCA53618.2021.9685491.

[8] S. Dustdar, C. Avasalcai and I. Murturi, "Invited Paper: Edge and Fog Computing: Vision and Research Challenges," *2019 IEEE International Conference on Service-Oriented System Engineering (SOSE)*, San Francisco, CA, USA, 2019, pp. 96-9609, doi: 10.1109/SOSE.2019.00023.

[9] Rajkumar Buyya; Satish Narayana Srirama, "Modeling and Simulation of Fog and Edge Computing Environments Using iFogSim Toolkit," in *Fog and Edge Computing: Principles and Paradigms* , Wiley, 2019, pp.433-465, doi: 10.1002/9781119525080.ch17.

[10] C. Mouradian, D. Naboulsi, S. Yangui, R. H. Glitho, M. J. Morrow and P. A. Polakos, "A Comprehensive Survey on Fog Computing: State-of-the-Art and Research Challenges," in *IEEE Communications Surveys & Tutorials*, vol. 20, no. 1, pp. 416-464, Firstquarter 2018, doi: 10.1109/COMST.2017.2771153.

[11] O. Skarlat, S. Schulte, M. Borkowski and P. Leitner, "Resource Provisioning for IoT Services in the Fog," *2016 IEEE 9th International Conference on Service-Oriented Computing and Applications (SOCA)*, Macau, China, 2016, pp. 32-39, doi: 10.1109/SOCA.2016.10.

[12] M. Etemadi, M. Ghobaei-Arani, and A. Shahidinejad, “Resource provisioning for IoT services in the fog computing environment: An autonomic approach,” *Computer Communications*, vol. 161, pp. 109–131, Jul. 2020, doi: 10.1016/j.comcom.2020.07.028.