Future Cities and Environment

REVIEW

ubiquity press

Zero Touch in Fog, IoT, and MANET for Enhanced Smart City Applications: A Survey

HANAA BASHEER

MAY ITANI

*Author affiliations can be found in the back matter of this article

ABSTRACT

Every year global cities swell in size. Modernization in techniques helps create sustainable cities for all. Cloud infrastructure providers strive to offer the highest level of availability across the infrastructure stack with the help of Fog Computing (FC) that was invented to deal with IoT interacting with wireless sensor networks (WSN) to enhance services. For intelligent devices to communicate efficiently, the Mobile ad-hoc network (MANET) in IoT is required. Intelligent devices that are connected together through the afore-mentioned networks may suffer from sudden errors in data storage and transfer thus the need for zero touch networks where devices can heal and adjust themselves to form autonomous networks based on data collected from different integrated network devices. In this work we aim to provide an overview of recent research works that combine FC, IoT and MANET technologies integrated together to build up sustainable cities. We illustrate works of three important applications that affect human daily life. While zero touch technologies are still in their early stages, we set a study of the latest information related to zero touch technologies and how AI supported by machine learning and data analytics constitutes a key enabler to fully autonomous future generation cities.

CORRESPONDING AUTHOR:

May Itani

Department of Mathematics and Computer Science, Beirut Arab University, Beirut, 1107–2809, Lebanon

ma.itani@bau.edu.lb

KEYWORDS:

MANET; fog computing; fog enabled IoT; zero touch; intelligent transportation; smart cities; sustainable cities

TO CITE THIS ARTICLE:

Basheer, H and Itani, M. 2023. Zero Touch in Fog, IoT, and MANET for Enhanced Smart City Applications: A Survey. *Future Cities and Environment,* 9(1): 5, 1–19. DOI: https://doi.org/10.5334/fce.166

1. INTRODUCTION

1.1. MOTIVATION

Statistics show that 66% of global population will inhabit urban regions by the year 2050. To guarantee enough supply of water, food, and energy for such large population together with economical, social, and environmental sustainability is a critical issue (Lai et al., 2020). The need for efficient systems that support many real time services in smart sustainable cities is arising (Devi and Gill, 2019). Diverse IoT devices have been escalating their ability to generate data transmission especially after the COVID 19 pandemic, where more and more devices demand for Internet connection. By 2025, the number of IoT devices (e.g. machines, sensors, and cameras) connected to the Internet will be generating 79.4 zetta-bytes as estimated by the International Data Corporation. This shocking growth has affected the data transmission through ad hoc network, though using MANET-IoT system gives better mobility services for users. Such systems will support real time services in smart cities such as rescue operations, military operations, and healthcare operations (Devi and Gill, 2019).

As stated in (Lai et al., 2020), a smart city should be an age-friendly environment as the World Health Organization defines it should "foster health and well-being and the participation of people as they age". Moreover, a smart city is also equivalent to a "smart sustainable city", supporting economic and environmental protection to meet the current and future challenges of its people, while leaving no one behind. Sustainable growth is created by technology where cities make better use of resources from electronic sensors that monitor and records actions to support citizens to make on resource utilization (Lai et al., 2020).

Usually IoT devices use the cloud as an easy-to-use platform for storing and processing data for wide range of applications. Even though the centralized data center model of cloud can deal with many types of applications, big data still overwhelms the network with limitations in real-time services and limits the communication efficiency due to device mobility. A large network bandwidth consumption overloads the core network and this may be enhanced using edge (Bittencourt et al., 2018; Lopes et al., 2017). Due to easy arrangement and low cost, the technology of wireless sensor networks (WSN) gives a significant role in terms of delay management and data collection. Sensors are distributed in real-time applications to observe the environmental data and make the cities sustainable and smarter. This can be achieved by remote sensing where sensors are connected in a wireless network to early detect environmental threats as in earthquake early detection systems. Moreover, continuous emission monitoring systems have helped develop market-based environmental policies to address air pollution. Advanced monitoring, reporting, and verification (MRV) features will continue to play a major role in enhancing the transparency, environmental integrity, and credibility of subnational, national, and regional emissions (Ramírez-Moreno et al., 2021). Users use devices connected through IoT with low powered sensors to monitor the energy-efficient wireless communication known as 'green communication' and make intelligent decisions. These devices are referred to as Green IoT devices. The main challenge of WSN is to make valuable services available on time. Since the cloud with Green IoT infrastructure is supposed to offer central storage, parallel processing, and real-time computations for critical and secure operations, the need for a mediator between the cloud and the physical devices arises which is 'Fog Computing'. 'Edge Computing' will also help where data computation is done close to the physical device before being sent to the cloud (Haseeb et al., 2021).

1.2. RELATED SURVEYS

Many recent surveys between the years 2018 till 2022 have addressed different aspects of fog computing and communications; however, no survey has comprehensively tackled fog together with ad hoc (specifically MANET) & IoT applications in smart cities with zero-touch integration. In this regards, we provide a list and a comparison of surveyed literature with surveys classified as either Fog & IoT or Fog & Ad hoc related studies. Despite the promising results achieved in the literature by using fog computing; still many challenges remain to be addressed especially regarding ad hoc network applications. Surveys in (Laroui et al., 2021) till (Tariq et al., 2019) considered IoT and fog integration. In (Salman et al., 2018; Alamer, 2021; Atlam et al., 2018; Elazhary, 2019; Fernando et al., 2016) authors illustrated concepts related to security issues in fog-enabled IoT in general and block chain technology integration in specific in (Alam and Benaida, 2020) & (Tariq et al., 2019). In (Laroui et al., 2021) Laroui et al. reviewed the role of cloud, fog, and edge computing in the IoT environment covering different IoT applications. Moreover; they investigate many control objectives like task scheduling, SDN/NFV, security and privacy, block chain, and smart applications. Their goal was to show how the edge computing is a solution instead of cloud computing for large scale problems. Firouzi et al. in (Firouzi et al., 2022) presented a tutorial of the existing solutions, models, and architectures from edge to fog and cloud. The authors focused on the interaction between cloud and edge/fog, including technical similarities and differences. The survey mentioned block chain integration as a solution for financial models but without any details. An IoT survey was conducted in (Salman et al., 2018), with the (software defined networking) SDN, (Network functions virtualization) NFV, and fog computing as solutions to overcome the main IoT challenges. Mentioned challenges included scalability, heterogeneity, big data, privacy and security. Enabling technologies with IoT were mentioned but not in the field of MANET with fog computing. Security and privacy was the main issue in fog computing for IoT in the review presented in (Alamer, 2021). Adding a software defined network (SDN) with the fog computing network system was presented as a solution for privacy and security threats. Many scenarios were presented to show how the SDN with fog computing improve IoT device performance. To show the enhancement while using SDN, a comparison between fog computing and SDN with fog computing was done. Another solution for security in fog computing and IoT was illustrated in Alam and Benaida (2020) by considering block chain. Authors introduced an approach to integrate block chain technology with fog-enabled IoT networks to increase security for smart devices. A review that focused on IoT applications enhancement using fog models was shown in (Atlam et al., 2018). This review discussed the challenges that appeared from integrating IoT with fog computing as well. Many IoT applications where fog computing played a vital role were introduced such as connected smart cars, smart traffic lights, smart home, etc. The review also stated vehicular networks as an application with fog computing and the ability to enable mobility methods but no details were provided. Hanan Elazhari in (Elazhary, 2019) mentioned three computation classes: IoT, cloud computing and mobile computing. The author compared different research area classes and discussed various developing computing paradigms and security threats. IoT computing was of major interest to the author where various requirements, protocols and standardization methods were considered. To gain cost efficient and real time IoT services, Niroshinie Fernando et al in their review (Fernando et al., 2016) presented the requirements for opportunistic fog computing to support mobile fog resources on-demand. The dynamic and ad-hoc nature of opportunistic fog computing makes it more prone to security threats than conventional fog. Security key challenging problems are authentication, trust in fog computing, and rogue fog nodes insertion.

As for (Tariq et al., 2019) Noshina Tariq et al, investigated the challenges to secure future digital infrastructure with big data. A comprehensive review of security requirements and challenges in fog-enabled IoT systems is presented. Moreover, big data privacy and trust concerns in relation to fog-enabled IoT are illustrated. This survey discussed blockchain as a key enabler to address many security related issues in IoT and fog computing. In (Kusuma) till (Gaouar and Lehsaini, 2021) authors surveyed the literature related to fog computing in ad hoc networks. The main concentration was on intelligent transportation systems (Singh et al., 2019; Laroui et al., 2021; Ullah et al., 2019) & VANETs (Kusuma; Pereira et al., 2019; Singh et al., 2019; Ullah et al., 2019; Escamilla-Ambrosio et al., 2018). In (Singh et al., 2019), Singh et al. presented state of the art architecture, applications, emerging radio access technologies, standardization, and project activities together with protocol stacks of the intelligent transportation system (ITS) in the USA, Japan, and Europe with their latest standards and challenges. Laroui et al. in (Laroui et al., 2021) considered intelligent transportation systems as one of smart applications while reviewing edge with IoT. Authors overviewed applications such as smart cities, smart homes, smart grid and healthcare in addition to smart transportation systems. Moreover, challenges related to privacy & security issues, & block chain in edge computing was introduced. Ullah et al. in (Ullah et al., 2019) provided a survey related to position based routing protocols for VANETs illustrating the fact that intelligent transportation system (ITS) supports better coordination among vehicles to achieve reliability. Gaouar et al also surveyed literature related to data dissemination methods in vehicular ad hoc networks (VANETs) related to cloud/fog computing with a comparison of both (Gaouar and Lehsaini, 2021). Ashraf et al. in (Ashraf et al., 2022) highlighted critical research involving application partitioning, task allocation, task execution and task resumption in fog computing applications. Only one survey by Machado et al. (Machado and Westphall, 2021) that was specific to for data forwarding approaches where block chain features were utilized for data forwarding incentives in multi-hop MANETs.

Table 1 below shows the significance of recent related surveys in the context of fog, IoT, and Ad-hoc technologies.

1.3. CONTRIBUTION

Our survey will introduce the new zero touch technology as a promising solution for future autonomous networks that will constitute a backbone for sustainable cities. Rejeb et al. in a very recent study (Rejeb et al., 2022) illustrated the importance of IoT in building smart cities and from 1,802 reviewed Scopus articles authors demonstrated that the major applications of the IoT for smart cities include smart buildings, transportation, healthcare, smart parking, and smart grids. To improve the overall well being of citizens, maintain efficient infrastructure systems, protect the ecological environment, and achieve sustainability goals, the incorporation of the IoT in smart sustainable urban systems is becoming a challenge to learn the user behavior be able to evaluate the realization of sustainable development goals. IoT is not a standalone technology as (Rejeb et al., 2022) states, it converges with various other intelligent computing paradigms, including cloud computing, fog computing, edge computing and 5G technologies. This integration offers on-demand, efficient, and powerful services improving communications, storage, and processing tasks, resource allocation, data transfer management, and overall convenient and efficient IoT processes that help in developing sustainable cities as stated earlier. We believe that our major contribution is in integrating the technologies together with considering the most three important applications as per sustainable city goals (Rejeb et al., 2022; Charneira, 2022).

REF.	YEAR	FOG/EDGE	IOT	ADHOC	SIGNIFICANCE
(Salman et al., 2018)	2018	✓	✓		Reviewing the SDN and fog computingbased solutions to overcome the IoT main challenges
(Atlam et al., 2018)	2018	✓	✓		Presenting benefits and challenges of state-of-the-art FC and IoT focusing on the architecture of fog-IoT application
(Elazhary, 2019)	2019	✓	✓		Discussing the lack of standard definitions of numerous emerging computing paradigms related to IoT devices Introducing technologies related to the IoT such as Internet of Nano Things, and the Internet of Underwater Things
(Tariq et al., 2019)	2019	✓	✓		Introducing big data, and fog architecture. Reviewing security requirements challenges in fog-enabled IoT systems and also the privacy of big data
(Singh et al., 2019)	2019	✓		VANET	Surveying state of the art future research directions in radio access technologies for autonomous and connected vehicles
(Ullah et al., 2019)	2019	✓		VANET	Surveying PBR schemes for city environment along with connectivity aware routing schemes Presenting a categorical evaluation of different architectures, path strategies, and carry-forward strategies
(Kusuma)	2021	✓		VANET	Surveying various security challenges, security algorithms used in VANETs Infrastructure
(Laroui et al., 2021)	2021	✓	✓		Investigating the role of edge/fog and cloud in IoT Covering different IoT use cases with Fog/edge
(Alamer, 2021)	2021	✓	✓		Reviewing the advantages of SDFC networks, with a consideration of security and privacy threats associated with the FC network topology and solutions
(Ashraf et al., 2022)	2022	✓	✓		Reviewing execution of resource-intensive tasks on mobile devices in distributed frameworks (using fog) Presenting challenges of establishing offloading decision to edge/fog server
(Firouzi et al., 2022)	2022	✓	✓		Presenting requirements, applications, and a comparison of computing paradigms of edge–fog–cloud IoT
(Gaouar and Lehsaini, 2021)	2022	✓		VANET	Classifying data dissemination schemes in vehicular ad hoc networks, vehicular cloud, and vehicular fog computing with their different architectures proposed
Our survey	2022	✓	✓	MANET	Introducing zero-touch technology integration with IoT – fog MANET

Table 1 Related surveys and their significance.

Many technologies and devices nowadays are combined to give a service to support a human request such as monitoring heart rate with a smart watch application and sending the result to the healthcare center if there is a need for urgent treatment. This motivated our work that provides a rich context to the researchers regarding technologies that can fit together to enhance many real-life situations. The methodology of this survey development comprises the following:

- **Survey literature;** where many survey papers were identified from literature and organized as in Table 1 to show the significance of recent related surveys in the context of fog, IoT, and Ad-hoc technologies. None presented the three technologies together. However, the surveyed papers were a rich source for both Fog and IoT technologies.
- **Fog computation framework;** was discussed as it constituted the backbone for both IoT and ad hoc networks technologies with a brief definition for each technology. Several different topics related to IoT (Peña and Fernández, 2019; Wagle and Pecero, 2019; Karamoozian et al., 2019; Tseng and Lin, 2018) and ad-hoc networks (Pathan, 2016; Vaquero and Rodero-Merino, 2014; Fang et al., 2017; Li et al., 2019; Leite et al., 2019) with fog were discussed in this survey.
- **Zero touch networks;** were introduced with an overview of recent zero touch technologies. The need for zero touch networks for urban services is considered so that operation will continue even if backhaul connectivity to the cloud is lost.
- **Discuss smart applications;** where many studies were briefed taking into consideration three main applications that demand a real time response. Smart city's goal is to give high quality life which includes quick efficient services whenever requested. Research papers were categorized based on each application and technologies used as shown in Table 2.
- **Identify challenges in future trends;** where we discussed some open challenges related to adopting zero touch techniques for the applications we reviewed throughout the survey. Recent studies are illustrated in Table 3.
- **Provide a recommendation for cities development;** where we referred to Reinforcement Learning (RL) the main zero touch technology to be used to develop sustainable smart cities.

REF.	MAIN APPLICATION & AIM	BACKBONE TECHNOLOGY
	Healthcare	
(Dang et al., 2019)	Processing health reports with less time and effort	MANET, CC and IoT
(Sarangi et al., 2021)	Presenting IoT healthcare devices for individual monitoring in actual time	FC, CC and IoT
(Hanumantharaju et al., 2021)	Optimizing load balancing in fog-enabled Health IoT	FC, CC and IoT
(Chudhary and Sharma, 2021)	Scheduling & allocating resources for healthcare tasks	FC, CC and IoT
(Abdelmoneem et al., 2020)	Optimizing task assignment schedule for available nodes to minimize execution cost	FC, CC-assisted by IoMT
(Mohammed et al., 2021)	Involving IoT devices in the healthcare procedure	FC and IoT
(Kai et al., 2016)	Proposing a model to analyze time-sensitive data using FC while sending longer-term data to CC	FC, CC and IoT
	Smart Transportation	
(Grover et al., 2018)	Smart city transportation with VANET and (FS)fog server integration: RSU to FS, FS to FS, and FS to CC	VANET, FC and CC
(Saroa and Aron, 2018)	Tracking parking capacity	VANET, FC and CC
(Zhang et al., 2017)	Multimedia and in-vehicle entertainment applications	VANET and FC
	Green Environment	
(Zahmatkesh and Al-Turjman, 2020)	Green IoT with less energy served by FC	IoT, sensor devices and FC
(Giordano et al., 2016)	Rainbow 3-layer architecture for heterogeneous intelligent applications including noise pollution, urban drainage networks, and a smart street environment	IoT, sensor devices and FC
(Maharjan et al., 2019)	Emergency information platform for disaster management	FC, CC and IoT
(Cheng et al., 2021)	Intelligent environmental protection service	FC, edge and IoT

Table 2 Sample surveyed literature based on application.

REF.	MAIN APPLICATION & AIM	ZERO TOUCH TECHNOLOGY ENABLER
(Gallego-Madrid et al., 2022)	Optimizing Traffic Flow	Reinforcement Learning
(Nagarajan et al., 2021)	Remote Real-time Health Monitoring	Deep Learning-Based Hierarchical Neural Network
(Kafy et al., 2021)	Achieving Sustainable Development	Cellular Automata and Artificial Neural Network
(Rezazadeh et al., 2020)	Resource Management Automation	Deep Reinforcement Learning
(Zhang Pettersson, 2022)	Battery Control Automation in Smart Cities	Reinforcement Learning

Table 3 Zero touch technology enabler in selected recent studies.

In section 2 we introduce fog computing and its integration with other technologies. Section 3 provides an overview of the computing technologies architecture, whereas section 4 surveys relevant literature related to MANET-IoT system and fog in Smart Sustainable Cities and classified as either healthcare, intelligent transportation, or environmental applications based on the fact that the main objectives of sustainable development goals as the UN agenda states are balanced between social, economic, and environmental issues. A discussion and open problems in the field of MANET – IoT & fog in smart sustainable cities where zero touch technologies is presented as a solution is illustrated in section 5. This will provide a starting point for researchers to fill in the gap with most up-to-date state-of-the-art research work.

2. FOG COMPUTING

Fog computing is a decentralized computing paradigm involving devices that have power and storage capacity such as smartphones, switches, routers, base stations, and other network management devices. It is designed to overcome the high latency problem of cloud computing by utilizing different resources. However, fog computing relies on the cloud to do complex processing (Naha et al., 2018). Fog computing infrastructures emerged recently to enhance response time and bandwidth usage overcoming the limitations of big data overwhelming the network in real-time services and limiting the communication efficiency due to device mobility. This incurs a large network bandwidth consumption on both edge and core networks as stated earlier. The fog-cloud paradigm combines the ability of executing smaller, localized applications at the edge and supports different IoT application requirements that convert collected data into almost real time processes (Bittencourt et al., 2018). The element "Fog" was created by CISCO and published in 2015, where its name refers to the real time support with faster response, minimum latency and minimum workload rate (Escamilla-Ambrosio et al., 2018). Recently an artificial intelligence based fog controller is presented to provide a versatile control mechanism to the fog layer. Also it offers potential solutions for the problems of fog-based Next Generation Internet of Things (NGIoT) systems (Kök et al., 2022).

The industry is beginning to move to a more decentralized infrastructure to improve security and trust between users and the rest of the network. Fog computing works as a decentralized mechanism where data and application can be stored temporarily between the data source and actual cloud as illustrated in Figure 1. The highly distributed data needs access operations to get the required stored data from different devices and from different locations using fog virtualized technology. New computing services are also emerging to deliver actionable insights for improving business productivity and reducing cost and risk (Rayes and Salam, 2019). In the following subsections we are going to review selected works related to IoT and Fog computing on one side, and ad hoc network and fog computing on the other side, then we will go through a general architecture of the new generation of computing technologies followed by MANET-IoT & fog in smart cities comparing different implementations in healthcare, intelligent transportation, and environment protection.

2.1. IOT AND FOG OVERVIEW

In 1999 Kevin Ashton the inventor of the term IoT said that "the IoT is about empowering computers so they can see, hear, and smell the world for themselves" (Gokhale et al., 2018). The International Telecommunication Union (ITU) defines the Internet of Things (IoT) as "global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies" (Domingo, 2012). The IEEE 1451–99 focused on developing a standard for IoT devices and systems. This standard defines a scheme for data sharing, compatibility, and trust of messages during network transmission where data will spread from different devices using different communication technologies (Logvinov et al., 2016). In 2015, Cisco conducted a successful simulation for Barcelona as a smart city, but they faced a big challenge in reality while adding dedicated new gateways and servers in every roadside cabinet. This wasn't possible due to limited cabinet space. The solution was to use a single fog node to provide a common platform at each cabinet for all services, and allow applications from different suppliers to coexist without interfering with each other. It also provides a unified platform for networking, which minimizes the system costs. Fog nodes are distributed as fog computing entities to enable the deployment of fog services. These can provide effective ways to overcome many limitations of the existing computing architectures that rely only on computing in the cloud and on end-user

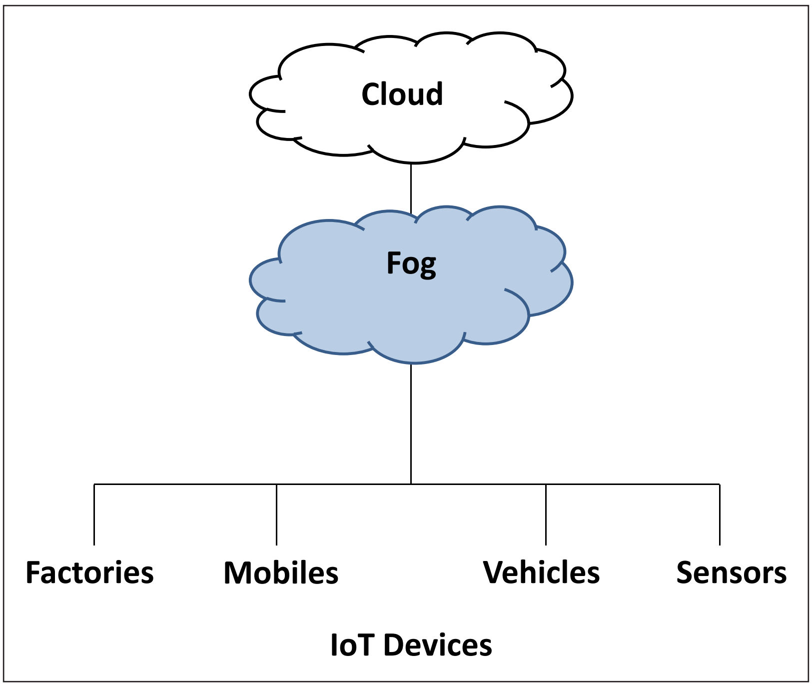

Figure 1 Fog layer as a decentralized storage between the data source and the cloud.

devices (Chiang, 2016). Miguel Angel and Isabel Muñoz mentioned in their paper (Peña and Fernández, 2019) that some developing aspects of Edge/Fog computing are not sufficiently supported by current IoT standards, or IoT topology management. For this they proposed an IoT model that extends the previous IoT architectural model, by adding three new entities: (i) IoT Data Flow Dynamic Routing Entity, (ii) IoT Topology Management Entity and (iii) IoT Visualization Entity. The model aimed to optimize response time, bandwidth consumption, storage, and other system properties by allowing data shared via different zones to be processed in any edge node, mid node or in the cloud. The selection of the computation nodes might change dynamically according to the conditions of the system (e.g. shared data, application requests, data volume, or any other relevant one). Wagle & Pecero in their paper (Wagle and Pecero, 2019) emphasized the need of IoT technical standardization due to various challenges that are explicitly stated in their work. They focus on data reliability, data security and collection of data in IoT intelligent devices. Reliability is specifically important in applications related to health care and mobile nodes services where data is collected at the IoT devices and transmitted to fog-cloud or to cloud directly. Data security can be deployed at one of three levels: device, edge, or cloud platform level. From the author's point of view, since IoT is a heterogeneous system, and knowing that multiple efforts are being done regarding IoT standardization by several alliances; there are still lots of concerns to be addressed to make the IoT ecosystem deployable. Karamoozian et al. in (Karamoozian et al., 2019) proposed in their work a solution to minimize the IoT applications' response time by distributing the processing elements modeled as graphs over the fog infrastructure. They modeled the system as an optimization problem using Gravitational Search Algorithm (GSA) meta-heuristic technique. Another work that was presented in (Tseng and Lin, 2018) by Tseng et al., focused on solving the overload problem in the cloud storage to achieve better latency for critical IoT/M2M applications by using Fog computing. Two fog nodes were suggested: one is the fog worker and the other is the fog manager. The fog worker offers virtual resources to run one IoT/M2M middle node, while the fog manager supervises the loading conditions of resources including arranging and scheduling containers and assigning tasks across different Fog workers.

2.2. AD-HOC NETWORKS AND FOG OVERVIEW

Ad hoc network is an on demand network, where mobile nodes can be connected at any time and at any location. Connection and disconnection of nodes is controlled by willingness to collaborate in the formation of a cohesive network and affected by the distance among them. In Mobile Ad Hoc Networks (MANETs) almost all nodes dynamically change positions all the time. The network configures itself on the fly and the nodes are autonomous and multidisciplinary. MANET has no infrastructure and the nodes use wireless connections such as WiFi (IEEE 802.11) connection, cellular, or satellite transmission to connect to various networks. Moreover MANETs permit creation of heavily loaded networks with no need for apriori-fixed and costly infrastructure by being the basis for future fog networks. Multi-hop networks as MANETs, lack the existence of physical security for network nodes and that imposes many threats including removal of network nodes and modification of the internal state of a node (Pathan, 2016; Vaquero and Rodero-Merino, 2014). A work published in 2017 mentioned a Fog-based MANET which is a new paradigm of a mobile ad hoc network with the advantages of both mobility and fog computing. The work claimed that it has a higher standard than a traditional Ad hoc network in terms of network security architecture, technology and routing protocol, where Fog- based MANET model can provide privacy protection, and security management. This model uses a cyclic redundancy check instead of a digital signature to reduce the protocol complexity and improve its energy efficiency (Fang et al., 2017).

VANETs are special types of MANETs, which allow vehicles to communicate with the internet using roadside units (RSU) (Pathan, 2016). In VANET, decentralized fog and centralized cloud co-exist and are paired to help vehicles with different kinds of services. Figure 2 shows the various vehicular applications that can be served either by centralized cloud in the data center or by the distributed fog close to the edge devices (Li et al., 2019). Applications that are involved with service management can be placed in the cloud which needs global information, while those that require vehicle real time service are supported by fog computing. The fog-enabled cellular network base stations provide one hop communication to access the services. The authors investigated the services location dynamic changing from fog server to another by enabling the cellular networks for the connected vehicles. Their scheme is to enhance decision making for service migration depending on QoS metrics satisfaction. One crucial matter is the Cloud-Fog interface, and how they cooperate with each other according to services and time scale. Even though fog computation is newly arising to overcome the restrictions of the cloud data centers, but the management issues still depend on cloud computing. It can be concluded that the applications that demand to be processed in real time can be served in the Fog level, while massive storage and heavy-duty computation will be assisted by the Cloud level. The information path from its frequency to granularity will be across the Fog-Cloud and Fog-Fog interfaces (Chiang, 2016). General speaking, VANET and connected IoT devices, are constantly evolving to

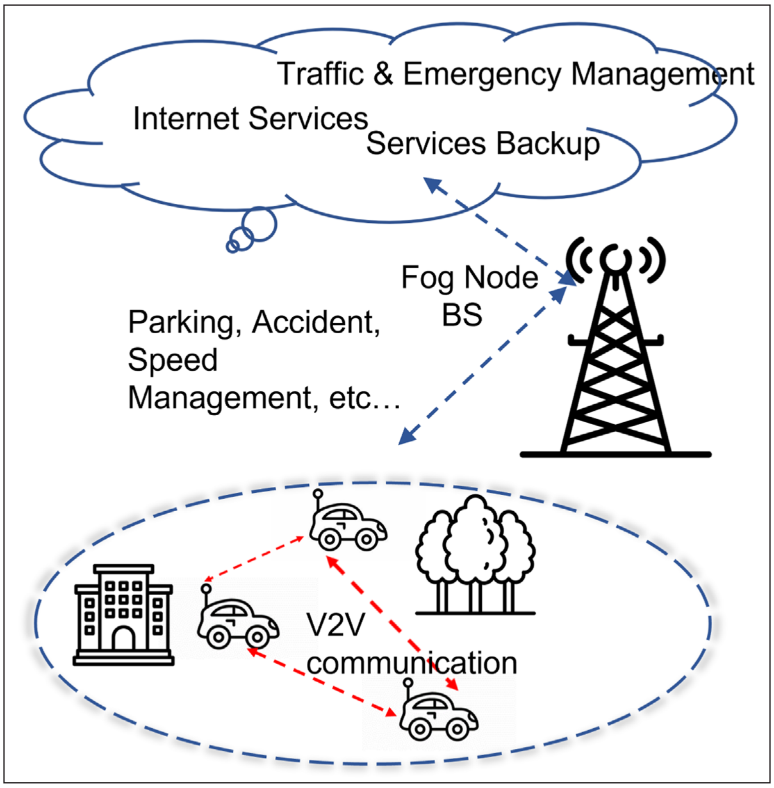

Figure 2 Vehicular applications.

become complex systems marked by clustering, and node mobility (Leite et al., 2019). Within this context, packet routing can be ineffective within time, so the best solution is to use Fog computing.

2.3. ZERO TOUCH TECHNOLOGY OVERVIEW

Mobile network management is becoming more complex with the hasty growth of smart Internet of things and increased requirement for services in the context of 5G and beyond networks. With the rapid increase of application requirements, the need for automation in network systems is becoming critical especially in smart cities applications. Thus the need for zero touch networks where urban services remain operative even if backhaul connectivity to the cloud is lost. By adopting zero touch technologies, self-configured, self-monitored, self-healed and self-optimized networks will emerge. Recent standardization efforts are being done in this domain to adopt zero touch service management in 5G and beyond networks. It is important to note that the architecture of the system need to be adaptive in nature so the automated features comply with the standards of the new technologies (Liyanage et al., 2022; Yannuzzi et al., 2017). Zero touch is simply 'no human intervention'. To achieve zero touch and bring intelligence to the network management system, ML adoption that helps in information processing, new knowledge generation, and intelligent decision making is required. A survey presenting the ML-based techniques that can be adopted to implement and enhance the autonomous network performance states that the main ML algorithms used to enable zero touch are supervised learning, unsupervised learning, semi-supervised and re-inforcement learning (Gallego-Madrid et al., 2022) and these are shown in Figure 3.

Supervised learning receives a training labeled data set for the purpose of classification and/or regression depending on the training sample whether it is discrete (classification) or continuous (regression). Supervised learning maps from the input feature space to the decision space. Classification algorithms assign a categorical label to each incoming sample. Such algorithms may be applied timely and accurate acquisition of traffic flow information which in turn helps in decision making for applications including traffic congestion alleviation, fuel consumption reduction, and various location-based services. Unsupervised learning algorithms include mainly clustering, neural networks and dimensionality reduction. These do not process labeled data sets and they are used, however, to identify patterns without predicting any output class for a given input. These algorithms are useful for grouping traffic flows with similar characteristics and assigning them to common slices to provide different levels of Quality of Service (QoS) depending on the available network resources. Dimensionality reduction is suitable for traffic data analysis and network congestion control. Semi-supervised algorithms merge the properties of supervised and un-supervised. They process a small amount of unlabeled data together with a large amount of labeled data for a better accuracy of the proposed model. The above stated algorithms are suitable for zero touch

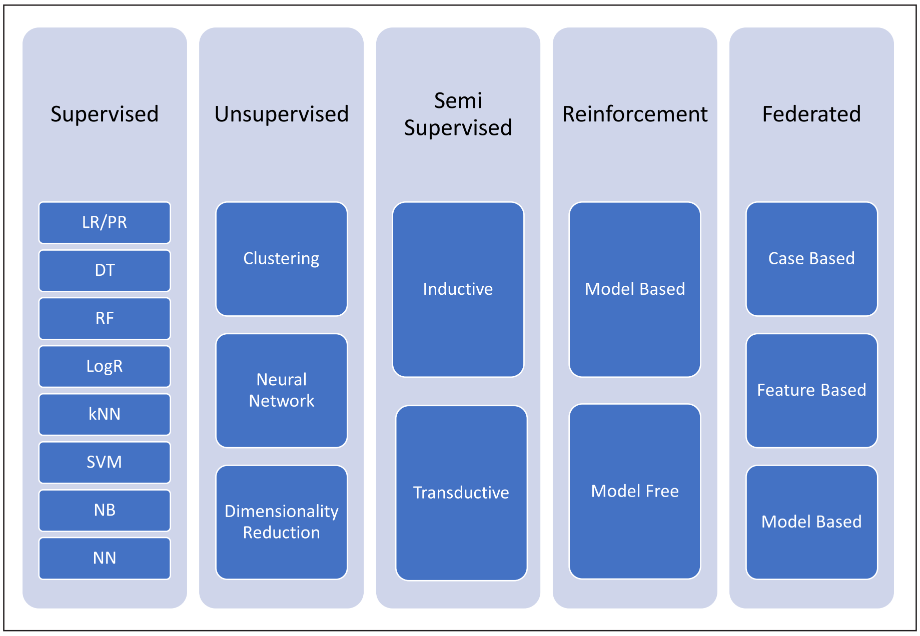

Figure 3 Machine learning technologies used to implement zero touch.

applications related to traffic flow prediction, road status and camera sensor information. These are considered local traffic critical data that are naturally generated and stored across different units in the network, e.g., vehicles, roadside units, and remote clouds. Zero touch technologies will provide support in storing such data in vehicles (Gallego-Madrid et al., 2022; Ye et al., 2018). Reinforcement learning (RL) involves an agent who learns and maps situations to actions in a way that maximizes a pre-defined reward function. The agent interacts with the environment and explores different actions in different situations, called states, to discover which decisions will yield the most reward without any previous knowledge. RL distinguishes itself from other learning paradigms, such as supervised learning approaches by relying on evaluative rather than instructive feedback. In this paper's context, RL helps in improving the quality of service in healthcare networks. These can be used in classification of healthcare data, selection of optimal gateways for data transmission and improving quality of transmission of real time patient data. Moreover, RL algorithms can be used for vehicular applications such executing computation intensive applications on resource constrained zero touch vehicles by solving the vehicular task offloading problem (Naous et al., 2023; Zhu et al., 2020; Kishor et al., 2021). As for federated learning (FL), it involves training a global model from several local models. It helps in preserving privacy since data is used locally. In vehicular applications, a global model is trained by collecting vehicle data with privacy protections. FL is expected to result in more efficient resource allocation in vehicular environments given the dynamic and decentralized features of vehicle networks. Another important aspect is the privacy issue since the exchange of vehicular sensor data is critical. FL provides a way to utilize vehicular big data while mitigating privacy risks. Moreover, FL provides a shorter response time due to the fact that the client performs actions based on the global knowledge and local data thus a lower response time in comparison to old conventional approaches that make decision at the central server side. FL can be integrated with edge computing to facilitate various real-time systems for vehicular IoT (Du et al., 2020).

3. ARCHITECTURE OF COMPUTING TECHNOLOGIES

Main architectures of new generation of computing technologies can be explained in four layers: IoT layer, edge layer, fog layer, and cloud layer (Dang et al., 2019). Some other references divide the architecture into three layers: Physical layer (IoT devices), Fog layer (edge devices with fog modules), and Cloud layer (Muneeb et al., 2021). The goals of Edge computing and Fog computing are similar and sometimes considered as one layer, although Fog computing is able to implement many applications and corporate smoothly (Dang et al., 2019). In both mentioned references the IoT layer is responsible of connecting millions of devices/sensors, and enables them to exchange important information amongst them, meaning that it can manage the smart-world infrastructures. These devices/sensors at the end will be used by users for Edge computing to process different applications. The IoT and the Edge computing are rapidly evolving in an independent manner. Edge computing model spreads the cloud computing services to the edges of the network to support decision-making operations, since they are close to the data sources. The Edge computing has acted as an intermediate layer that connects cloud data centers to edge IoT devices (Taheri and Deng, 2020). Therefore, IoT devices/sensors can benefit from the high computational capacity and large storage that will be available. The fog layer is responsible for compression, encryption, act as temporary storage, and help in data pre-processing (Sarangi et al., 2021). Cloud layer is mainly responsible for more complicated tasks, resource consuming tasks and updates of rules for detection on the fog layer. The cloud computing capabilities are brought to the edge of the network, to choose the suitable path to enable the computation and storage capacities for the end users with low latency and reduce network bandwidth for sensitive applications (Khan, 2016). Figure 4 shows the four layers based on (Dang et al., 2019).

4. MANET-IOT SYSTEM AND FOG IN SMART SUSTAINABLE CITIES

Smart cities are the urban areas that are involved with all smart systems such as network communication technologies with sensors and actuators. Smart systems can be viewed as extended IoT technologies whereas smart sustainable cities involve new techno–urban phenomenon that emerged around the mid–2010s, and it is still in its early stages of development (Bibri, 2018). IoT is considered as one of the key components of the information and communications technology (ICT) infrastructure of smart sustainable cities (Taheri and Deng, 2020). Three common models of communication in ICT infrastructure exist (i) Device-to-Device (D2D), (ii) Device-to-Server (D2S), and (iii) Server-to-Server (S2S) and these constitute models involving sensor and actuator technologies, wireless technologies, ad hoc networks, fog and cloud computations and smart things. Several popular application level protocols used by the applications in a smart city depend on fog computing such as HTTP, CoAP, IoTivity ...etc (Sultan et al., 2021). Through the past few years many systems were invented and categorized as a smart system for sustainable smart cities and these are very important nowadays enhancing many life styles. Many studies aim to deal with IoT-related big data applications in parallel with economic growth and the quality of life in smart cities, without highlighting their significance in improving environmental sustainability in the smart sustainable cities. Big data applications qualified by the IoT are created to serve a variety of domains of smart sustainable cities with respect to operational functioning, management, and planning side by side with of environmentally sustainable development goals (Bibri, 2018). Environmental urban sustainability depends on dedicated, powerful software applications to log urban infrastructures, collecting data sensors and mobility patterns. The analysis of big data will help extract computationally activity, behavior, process, and environment models to identify and gain predictive decision–making for new structures, systems, and processes to match smart sustainable cities in order to increase their contribution in environmental sustainable development (Bibri, 2018). As stated earlier in introduction, the three main elements of achieving sustainability are quality of life, economical manner, and natural environment. In Nov. 1, 2018, Jim Frazer presents nine applications for smart cities which include building environment, energy infrastructure, telecommunications, transportation and mobility, health and human services, water and waste water, waste management, public safety, and payments and finance (Frazer, 2018).

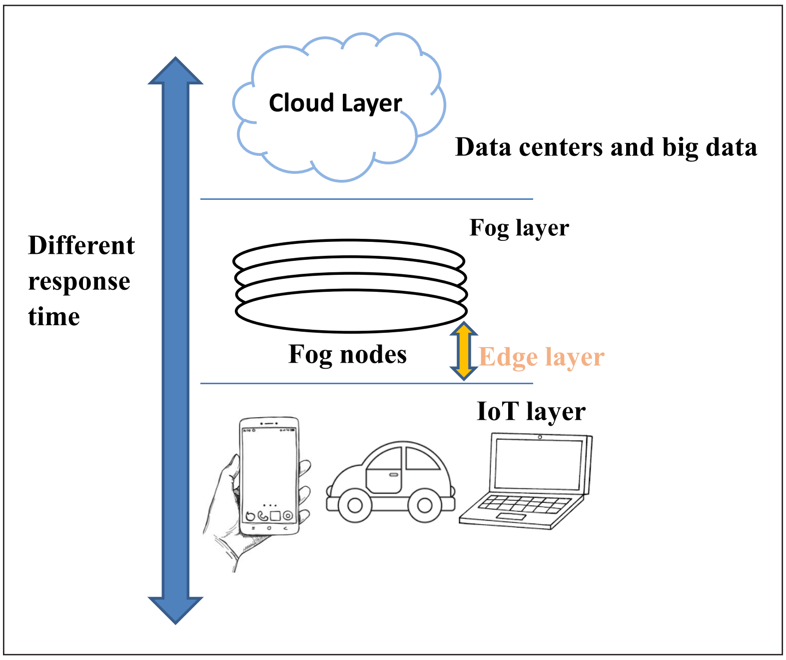

Figure 4 Fog computation architecture.

Many papers in literature categorized the smart city needs and services into classes. In 2010 Giffinger et al. (Giffinger and Gudrun, 2010) defined the smartness of a city via six measures where the city should perform well. These include (i) smart economy; (ii) smart people; (iii) smart governance; (iv) smart mobility; (v) smart environment and (vi) smart living in which 'Smart Ranking' of cities was based on.

In this section we consider three commonly used applications in smart cities which match with the basic concepts of sustainability such that low latency is required. In this regard, data transfer to the cloud will neither be practical no efficient and the support of FC, IoT & MANET technologies is required to overcome data processing limitations. The applications considered in our study fall under the categories of smart people/living domain, smart mobility domain, and smart environment domain. These applications with the supporting technologies will be discussed in the following three subsections entitled MANET-IoT and fog in healthcare field, MANET-IoT and fog in intelligent transportation, and MANET-Green IoT and Fog in environment protection. After surveying literature in every application field, we then consider the improvement that can be done for each application when moving to zero touch networks.

4.1. MANET-IOT AND FOG IN HEALTHCARE APPLICATIONS

There have been industrial revolutions throughout the history of engineering and healthcare industry. The initial thought of healthcare industry was started in the late of 1970s. To gain the benefit from the healthcare industry, installed applications must be easy to use and compatible with services provided by industrial standards (Sarangi et al., 2021). In United States half the hospitals use rural communication (Weisgrau, 1995). With nowadays hectic life, people are becoming less aware of their regular health checkups and clinical visits especially during the pandemic lockdown. This creates a need for introducing healthcare applications country wide to alert individuals about their health since the well-being of people will affect their work efficiency and thus the overall society growth. A healthcare application has the facilities to help people via personal devices that are connected to the network. The mobility of personal devices make it easy to get personal health reports with less time and effort (Dang et al., 2019). Health databases grow rapidly and need to be stored and quickly analyzed for availability. Fog computing helps in linking the healthcare data with applications, since it works as a middle layer between the user device layer and the cloud layer, this is as if fog computing turned the IoT devices to be involved in the healthcare procedure. E-healthcare services face many challenges regarding collecting and analysis data, securing and trusting e-healthcare services, and providing a good privacy for the users' health situation Hanumantharaju et al. (2021). For explanation of how the healthcare works, we can say that all health indicators can be obtained by the wearable sensors of the patient. Moreover, any client has the ability to enter information into his or her mobile and get feedback from the healthcare supervisor as shown in the sketch of Figure 5.

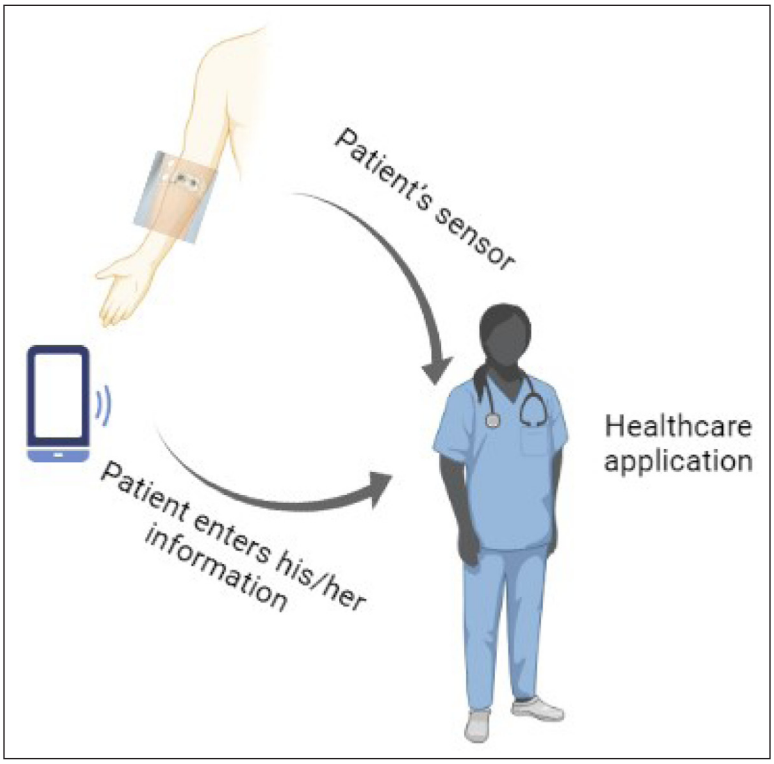

Figure 5 E-healthcare services involving sensors.

With this facility many critical situations can be controlled instantaneously. For more explanation, here we will discuss four examples of IoT healthcare devices that were listed in (Sarangi et al., 2021) where the collected data from these devices can be transferred in actual time to the healthcare center to take quick action and save lives:

- Diabetes, this disease impairs the production of insulin in the body, so continuous monitoring of blood glucose levels via IoT device is needed to help patients in controlling their diet and take proper medication at the right time.
- ECG monitoring in actual time is very important to give confidence information about heartbeat, rate, and prolonged QT intervals. This can be done through IoT- enabled technologies.
- Monitoring body temperature, gives an indicator about patient situation.
- Pulse oximetry can help measuring the blood oxygen saturation level continuously. Using IoT pulse oximetry device would make monitoring and triggering alerts for actions easy.

Due to the huge amount of data being generating at the same time, and the necessity of being sent as quickly as possible, industry should think seriously to overcome any possible error and data loss. Hence in such critical scenarios, quality of service cannot be guaranteed. So technical challenges have given rise to fog computing (Sarangi et al., 2021). Studies showed different techniques to improve the health services. Internet of Healthcare Things (IoHT) framework has emerged to provide improved reliable and cheaper health services (Chudhary and Sharma, 2021). This study has proposed architecture to forward critical heterogeneous health data from device to either fog or cloud based on traffic situation in a way that load balancing is optimized. The work has been proved to reduce the latency and packet loss while maximizing the throughput in e-healthcare systems. Note that in this study the algorithm selects fog nodes based on the buffer demand. It should be noted that when When the buffer size is high, the packet delivery rates in fog layer reduces and this maybe considered a future enhancement to take into consideration. Another study in (Abdelmoneem et al., 2020) proposed mobility-aware scheduling and allocation protocols for healthcare via an efficient healthcare architecture. A mobility-aware heuristic based scheduling and allocation approach was introduced to allocate healthcare tasks among computational fog and/or cloud nodes. It dynamically balances task computation distribution according to mobile patients and the temporal/spatial residual of their sensed data. This will provide fast response time enhancing the performance in terms of latency and energy consumption. It is noteworthy to state that the authors used a case study that consists of five patient rooms with one nurse station to evaluate the proposed approach. Hence the need for high scale and more realistic scenarios to be studied and tested. One recent study (Mohammed et al., 2021) investigated the use of bio-ankle sensors in blockchain-fog-cloud-assisted IoMT environment taking into consideration the related challenges that constitute mainly cost-efficient scheduling, security, and data validation. The aim of the research was to minimize execution cost of health applications by proposing an optimal task assignment schedule to the available nodes. Simulation results proved that the proposed method minimized system service cost compared to all existing bio-inspired healthcare systems thus enhancing performance. Efficient healthcare services are emerging with the aid of wireless communication and artificial intelligence where ultra-reliability and zero-touch network management are employed. Chang et al. in (Chang and Lin, 2021) states that patient data even genetics should be well managed and analyzed to optimize the patient care and introduces the quanta healthcare AIoT platform where a cloud-based collaboration platform designed for hospitals with different professions to collaborate over a virtual clinic on demand involving Artificial Intelligence (AI) and Internet of Things (IoT). Quanta Smart Telehealth is another platform that tackles the problems of discharged patients, elderly care and chronic disease patients at home or care center. Patients are to be monitored over the cloud and the medical devices used where AI and algorithms will be applied to monitor the changes of vital signs measured over time for early warning (Chang and Lin, 2021).

4.2. MANET-IOT AND FOG IN INTELLIGENT TRANSPORTATION

Most important control objective in smart cities is to improve the performance of the IoT technologies and ad hoc networks to develop users' services. One of the important services is Intelligent Transportation (IT) that aims improving road safety and allows comfortable travels. Vehicular Ad hoc Networks (VANET) is considered smart transportation backbone. Note that VANET is a special case of MANET that uses IEEE 802.11p-2010 standard protocol (Committee et al., 2007). Smart vehicles can be connected to each other to form a vehicle to vehicle communications (V2V), through the use of the onboard units (OBUs) as a communication device. A vehicle also can be connected to the internet as (V2I) communication through the road side units (RSUs) that are placed in certain points on the road sides. In Cisco's white paper, proposed for IT and operational technology professionals, a new model has been presented and explained for analyzing and acting on IoT data. Most of VANET applications are based on periodic exchange of requested and automated safety messages between nearby vehicles and between vehicles and nearby road side communication units. Here comes the benefit of the combination of FC and VANET. Efficient vehicle detection (VD) is needed with the increase of vehicles number. A study in (Abdullah and Ali, 2021) proposed an efficient vehicle detection system using machine learning to detect vehicles at different weather conditions such as sunny, rainy, cloudy and foggy days. Other studies like that in (Kai et al., 2016) presented techniques to analyze time-sensitive data at edge nodes, rather than sending it to the cloud. Sensitive data is processed through IoT and FC, while spatial data is sent to the cloud for historical analysis and longer-term storage. The FC is like a near-end computing agent between the user end devices and the servers. In (Grover et al., 2018), three types of connections made by fog server in VANETs are mentioned:

- RSU to Fog Server used to disseminate safety and non-safety messages between vehicles and internet and also between RSUs themselves. RSUs can be considered as supported devices for Fog computation, and the communication can be created as wired/wireless between each RSU and the fog server.
- Fog Server to Fog Server where fog servers located at different points to control many resources for the nearby area, the communication between fog servers can be wired/wireless communication. Moreover vehicles can be a connected control center.
- Fog Server to Cloud in which the cloud is the central controller that can support VANET with information from a database such as the Vehicles as a Service (VaaS) which is a business model solution. Each fog server provides many services to different users at specific locations, this is done with the support of the cloud center that collect the information received from fog servers to perform centralized computation. Then fog servers carry the information received from cloud to the users.

Services of Fog computing in vehicular scenario are not as much as for vehicular cloud computing (VCC). However traditional cloud computing is not appropriate for many VANET application services due to the rapid change of vehicles locations and the request messages that should be served in real-time. This is the reason why FC together with the nearest network edge are needed to deal with dynamic environments of quick changes in vehicles' locations. Below are samples of transportation applications that are supported by the Fog computing layer that can be appropriate in smart cities (Grover et al., 2018; Saroa and Aron, 2018):

- Smart traffic light that is considered a very important application to optimize traffic at traffic light junctions. Different FCs can be used at traffic light junctions to compute the duration of each signal based on the traffic situation around the junction.
- Parking system which is very useful for drivers in crowded cities at rush hours. A combination of FC, RSUs and CCs technologies is used to find a free spot. With the use of FC the parking slots must be installed with sensors to keep on tracking parking places and giving signals as empty or full. The sensors keep sending data towards the fog nodes that are connected to the smart vehicle through the ad hoc networks.
- Road traffic situations where fog computing can be used for transferring safety and non-safety messages, such as a traffic jam at some point on the road, or the existing of an accident. This information can be carried by the fog servers to vehicles approaching towards this point to choose another available path.
- Multimedia and in-vehicle entertainment considered one of the potential applications in fog-computing-based Internet of Vehicles. (Zhang et al., 2017).

The authors in (Grover et al., 2018) discussed IoT applications that can be implemented using fog computing but they didn't provide any layout and/or implementation of these applications.

A new era for cities with fog computing is emerging where autonomous operation at the edge is required to ensure operation of urban services when backhaul connectivity is unavailable. Critical tasks including smart and autonomous control of energy distribution boards inside new generation of street cabinets that offer strategic control points for the city monitoring, analyzing, and controlling different processes. Street sensors record traffic and monitor aspects such as vehicle numbers, speed, length, and other variables including estimations of queue sizes and waiting time at signalized intersections. Data collected from sensors is processed at gateways where sophisticated algorithms are installed. By pushing the computation to a fog node, less burden on vendors will be implied thus allowing them to focus on more important aspects such as applications and software components (Yannuzzi et al., 2017). To provide ubiquitous connectivity as for the purpose of multimedia and in-vehicle entertainment and others, 6G technology will be utilized where non terrestrial platforms aid the terrestrial network. Intelligent communications environments will be maintained with pervasive artificial intelligence and large-scale automation. in this context, a framework that uses Flying Ad-Hoc Networks (FANET) consisting of a set of Unmanned Aerial Vehicles (UAVs) to provide a remote geographic area with computing and networking facilities is proposed in (Grasso et al., 2022). Note that authors didn't consider the association of flying platforms to ground devices and this will be an important issue to elaborate on in future research especially in rural areas and emergency situations.

4.3. MANET-GREEN IOT AND FOG FOR ENVIRONMENT PROTECTION

For monitoring the environment in a smart sustainable city, many sensors must be located in fixed points. The IoT sensors are responsible of transmitting information frequently from the nearby environment to the servers involved. Exchanging such critical information needs high cost of energy. Fog technology is used to increase the overall performance of the IoT applications by using the local resources to perform some services. In this way energy consumption is reduced since the fog layer is placed closer to the end user. FC is the most suitable choice for supporting the Green IoT system since it depends on micro centers that are limited in processing, communicating, and storing capabilities. Fog technology has the possibility to improve the performance of the real-time interactive applications and can deal with different cloud providers. Green IoT system mainly gives a good protection for the environment in smart sustainable cities. The combination of CC and FC plays a significant role in supporting Green IoT system. Security between Cloud computation platforms and IoT sensors and devices is important (Zahmatkesh and Al-Turjman, 2020). Decentralized algorithms have been explored as multi-agent systems for developing large-scale cyber-physical applications. Rainbow adopts the combination of multi-agent systems and fog computing. To allow the creation of distributed and swarm real time intelligence applications many proposal methods were illustrated in (Giordano et al., 2016) which include:

- Mapping the noise pollution on an urban area, and showing how Rainbow can be exploited to run swarm intelligence algorithms in order to realize cyber physical system (CPS) applications owning properties such as adaptation, fault tolerance and self-reconfiguration.
- Designing a CPS for urban drainage networks, which is able to reduce their environmental impact when heavy rainfall event occurs, and a set of preliminary simulation results underlining the benefits of the proposed system.
- Providing a smart street environment to furnish the city with an IT infrastructure that offers services to the citizens which can be expanded to cover a wider area.

In another perspective, the earth is changing continuously, so to save the planet we seek deep attention towards the natural resources, and how to treat the growth of the waste especially in urban cities. Smart garbage management system is a solution that was presented in (Saroa and Aron, 2018). The authors mentioned that FC and CC technology can be used to collect and manage the waste more efficiently. The idea is to present a three-layer architecture that permits easy development of smart sustainable city applications and bring the computation close to the physical part. Another study in (Nair et al., 2021) illustrated how the existing waste management systems that involve human intervention at each stage can causes serious health issues to sanitation workers. Moreover waste management practices affect the health of people living around dump yards. The study proposed a new concept of IoT enabled zero touch waste management platform for smart cities that consists of a smart dustbin, autonomous waste collection truck, smart dump yard and waste management center. The study presents an architecture for the proposed smart waste management platform with a routing algorithm to provide shortest route data to cover all garbage bins. The proposed platform aims to address the United Nations Sustainable Development Goals 3: Good Health and well-being, 6: Clean Water & Sanitation and 11: Sustainable Cities and Communities by the implementation of smart waste management system (Nair et al., 2021). Deploying the proposed system in real life scenarios and applying AI-enabled algorithms to optimize the route and plan ahead should be implemented.

In (Maharjan et al., 2019) Maharjan, B. et al. considered emergency situations of the environment where authors presented an information platform that can help in communication whenever man-made or natural disasters threatens happen. Since in such scenarios communication links are congested with high data traffic where people broadcast the disaster, the study involves utilizing IoT by proposing a software-defined communication network that combines IoT, FC, CC, peer-to-peer computing, and delay-tolerant network to enable an effective emergency-response information platform. In (Cheng et al., 2021), Cheng et al. discussed in their paper the concept of fog/edge computing being used to enhance the load burden generated by hundreds of millions of IoT devices that can be applied in the field of environmental protection and industry applications. The paper proposes a wise environmental oriented IoT gateway software architecture after presenting the problems of intelligent access to environmental protection devices, safe transmission of environmental protection data, quick connection of environmental protection platform and many others. It then provides results of testing and verifying stability and reliability of this intelligent gateway. The intelligent gateway needs to be further enhanced on the communication and security side knowing that the IoT embedded system has limited time and space resources. Sustainable environment design is considered to achieve the sustainable development of society, and to ensure the availability of resources needed by future generations. Sustainable design is initiated for the green environment protection and the development of green design aims to be service-oriented. The natural environment needs to bear more domestic waste and medical waste in unusual situation. Applying the principle of zero-touch to green environment design can improve the feasibility of green design and the necessity of intelligent interaction design (Cengjuan, 2022).

Table 2 summarizes some papers that were classified and used as references in this section.

5. CHALLENGES AND OPEN PROBLEMS

In this section, we discuss some challenges that arise when adopting zero touch techniques for healthcare, transportation and environmental applications in smart cities. We present recent zero touch research in the smart cities domain in Table 3 and highlight open research.

Telemedicine is becoming a challenge in healthcare where medical care is to be provided virtually between doctors and patients who will communicate via video conferencing and transfer data through mobile connection, satellite technology or the Internet. Healthcare stakeholders need to move towards integrating new technologies (Romanovs et al., 2021). From other perspective, automation of resource management needs to be considered. Works on deep reinforcement learning based network slicing orchestration systems are being done where deep RL is adopted to orchestrate the resources of the RAN, computing nodes, and transportation network. To optimize the performance of traffic flows, a smart agent learns from the system and dynamically orchestrates resources (Gallego-Madrid et al., 2022). Technical and nontechnical challenges including safety, security, resilience, and business and operational benefits regarding traffic regulation tasks in the fog layer need to be addressed (Yannuzzi et al., 2017). Another study that involves enabling the automation of resource management and orchestration in 5G and beyond networks using an advanced continuous deep reinforcement learning (DRL) method called twin delayed deep deterministic policy gradient algorithm is proposed in (Rezazadeh et al., 2020) where a multi-objective approach is employed where the central unit learns to self-resources taking into consideration energy and bandwidth resources. Battery control automation is also proposed in (Zhang Pettersson, 2022) to enhance mobile communication services in radio access technologies to serve the purpose of zero touch technology in smart cities where optimal policies for battery control using reinforcement learning methods are proposed. Upon analyzing the studied works, we notice that the main zero touch enabler technology is Reinforcement Learning (RL). RL is used to generate intelligent infrastructure to develop sustainable smart cities. Domains include traffic analysis and management, specific healthcare domains including diabetes, heart disease, cancer, and Parkinson disease and other applications such as agriculture and smart farming, weather forecasting, etc… More attention should be given to practical real-time scenarios including scalability, accuracy, prompt and secure data analysis.

6. CONCLUSION

Fog computing plays a critical role in supporting IoT devices by receiving data in real time and reducing information transmission time latency. The combination of fog and cloud computing paradigms is integrated with Ad-hoc & IoT systems to decentralize the services and bring applications and services towards the edge of the network. The MANET-IoT framework plays an important role with fog computing in smart cities' services. This paper has shown the importance of fog computing in IoT applications. Building smart cities is the goal of every government, meaning that developing life style is done by using intelligent devices to obey the citizens requirements. Three important MANET-IoT applications that rely on fog computation have been discussed and they can be applied to cities depending on the availability of MANET and IoT devices. However, many challenges should be taken into consideration when building such systems including strong security and privacy methods to protect distributed data and to guard users' privacy. Moreover, fog computing together with artificial intelligence including machine learning and deep reinforcement learning techniques is being a key enabler for offering quick service management with zero touch automated problem resolution for smart cities applications.

FUNDING INFORMATION

Research needs no funds. As for article processing charges in case of acceptance in Future Cities and Environment Journal, these will be self – funded by authors. Corresponding author has agreed to pay article processing charges if the manuscript is accepted.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Hanaa Basheer: Visualization; Conceptualization; Methodology; Writing – Original Draft; Writing – Review and Editing.

May Itani: Conceptualization; Methodology; Writing – Original Draft; Writing – Review and Editing; Supervision.

AUTHOR AFFILIATIONS

Hanaa Basheer orcid.org/0000-0002-0900-090X
Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, 10001, Iraq

May Itani orcid.org/0000-0002-0738-0822
Department of Mathematics and Computer Science, Beirut Arab University, Beirut, 1107–2809, Lebanon

REFERENCES

Abdelmoneem, RM, Benslimane, A and **Shaaban, E.** 2020. Mobility-aware task scheduling in cloud-fog iot-based healthcare architectures. *Computer Networks*, 179: 107348. DOI: https://doi.org/10.1016/j.comnet.2020.107348

Abdullah, MN and **Ali, YH.** 2021. Vehicles detection system at different weather conditions. *Iraqi Journal of Science*, 2040–2052. DOI: https://doi.org/10.24996/ijs.2021.62.6.30

Alam, T and **Benaida, M.** 2020. Blockchain, fog and iot integrated framework: review, architecture and evaluation. arXiv preprint arXiv:2006.03596. DOI: https://doi.org/10.31219/osf.io/8k7j9

Alamer, A. 2021. Security and privacy-awareness in a software-defined fog computing network for the internet of things. *Optical Switching and Networking*, 41: 100616. DOI: https://doi.org/10.1016/j.osn.2021.100616

Ashraf, M, Shiraz, M, Abbasi, A and **Albahli, S.** 2022. Distributed application execution in fog computing: A taxonomy, challenges and future directions. *Journal of King Saud University-Computer and Information Sciences*. DOI: https://doi.org/10.1016/j.jksuci.2022.05.002

Atlam, HF, Walters, RJ and **Wills, GB.** 2018. Fog computing and the internet of things: A review. *Big data and cognitive computing*, 2: 10. DOI: https://doi.org/10.3390/bdcc2020010

Bibri, SE. 2018. The iot for smart sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability. *Sustainable cities and society*, 38: 230–253. DOI: https://doi.org/10.1016/j.scs.2017.12.034

Bittencourt, L, Immich, R, Sakellariou, R, Fonseca, N, Madeira, E, Curado, M, Villas, L, DaSilva, L, Lee, C and **Rana, O.** 2018. The internet of things, fog and cloud continuum: Integration and challenges. *Internet of Things*, 3: 134–155. DOI: https://doi.org/10.1016/j.iot.2018.09.005

Cengjuan, W. 2022. Research on the development trend of green design in the post-epidemic era. In: *2022 International Conference on Social Sciences and Humanities and Arts (SSHA 2022)*. Atlantis Press. pp. 277–281.

Chang, T and **Lin, YB.** 2021. Aiot for digital transformation of healthcare. *IEEE CTSoc-NC T NEWS on Consumer Technology*.

Charneira, NMV. 2022. Monitoring Smart Sustainable Cities: Business Intelligence approach to Smart Sustainable Cities. Ph.D. thesis.

Cheng, Y, Meng, H, Yuan, L and **Lei, Y.** 2021. Research on edge computing technology of internet of things based on intelligent and environmental protection. In: *2021 IEEE International Conference on Consumer Electronics and Computer Engineering (ICCECE)*. IEEE. pp. 581–590. DOI: https://doi.org/10.1109/ICCECE51280.2021.9342449

Chiang, M. 2016. Fog networking: An overview on research opportunities. arXiv preprint arXiv:1601.00835.

Chudhary, R and **Sharma, S.** 2021. Fog-cloud assisted framework for heterogeneous internet of healthcare things. *Procedia Computer Science*, 184: 194–201. DOI: https://doi.org/10.1016/j.procs.2021.03.030

Committee, ICSLS, et al. 2007. Ieee standard for information technology-telecommunications and information exchange between systems-local and metropolitan area networks-specific requirements part 11: Wireless lan medium access control (mac) and physical layer (phy) specifications. *IEEE Std*, 802(11).

Dang, LM, Piran, MJ, Han, D, Min, K and **Moon, H.** 2019. A survey on internet of things and cloud computing for healthcare. *Electronics*, 8: 768. DOI: https://doi.org/10.3390/electronics8070768

Devi, M and **Gill, NS.** 2019. Mobile ad hoc networks and routing protocols in iot enabled. *Journal of Engineering and Applied Sciences*, 14: 802–811. DOI: https://doi.org/10.36478/jeasci.2019.802.811

Domingo, MC. 2012. An overview of the internet of things for people with disabilities. *Journal of Network and Computer Applications*, 35: 584–596. DOI: https://doi.org/10.1016/j.jnca.2011.10.015

Du, Z, Wu, C, Yoshinaga, T, Yau, KLA, Ji, Y and **Li, J.** 2020. Federated learning for vehicular internet of things: Recent advances and open issues. *IEEE Open Journal of the Computer Society*, 1: 45–61. DOI: https://doi.org/10.1109/OJCS.2020.2992630

Elazhary, H. 2019. Internet of things (iot), mobile cloud, cloudlet, mobile iot, iot cloud, fog, mobile edge, and edge emerging computing paradigms: Disambiguation and research directions. *Journal of Network and Computer Applications*, 128: 105–140. DOI: https://doi.org/10.1016/j.jnca.2018.10.021

Escamilla-Ambrosio, P, Rodr´ıguez-Mota, A, Aguirre-Anaya, E, Acosta-Bermejo, R and **Salinas-Rosales, M.** 2018. Distributing computing in the internet of things: cloud, fog and edge computing overview, Springer, pp. 87–115. DOI: https://doi.org/10.1007/978-3-319-64063-1_4

Fang, W, Zhang, W, Xiao, J, Yang, Y and **Chen, W.** 2017. A source anonymity-based lightweight secure aodv protocol for fog-based manet. *Sensors*, 17: 1421. DOI: https://doi.org/10.3390/s17061421

Fernando, T, Loke, S, Avazpour, I, Chen, F, Bakhshandehabkenar, A and **Ibrahim, A.** 2016. Opportunistic fog for iot: challenges and opportunities. *IEEE internet of things journal*, 3: 854–864.

Firouzi, F, Farahani, B and **Marinšek, A.** 2022. The convergence and interplay of edge, fog, and cloud in the ai-driven internet of things (iot). *Information Systems*, 107: 101840. DOI: https://doi.org/10.1016/j.is.2021.101840

Frazer, J. 2018. The nine critical applications of a smart city. URL: https://www.arcweb.com/blog/nine-critical-applications-smart-city.

Gallego-Madrid, J, Sanchez-Iborra, R, Ruiz, PM and **Skarmeta, AF.** 2022. Machine learning-based zero-touch network and service management: A survey. *Digital Communications* *and Networks*, 8: 105–123. DOI: https://doi.org/10.1016/j.dcan.2021.09.001

Gaouar, N and **Lehsaini, M.** 2021. Toward vehicular cloud/fog communication: A survey on data dissemination in vehicular ad hoc networks using vehicular cloud/fog computing. *International Journal of Communication Systems*, 34: e4906. DOI: https://doi.org/10.1002/dac.4906

Giffinger, R and **Gudrun, H.** 2010. Smart cities ranking: an effective instrument for the positioning of the cities? *ACE: architecture, city and environment*, 4: 7–26. DOI: https://doi.org/10.5821/ace.v4i12.2483

Giordano, A, Spezzano, G and **Vinci, A.** 2016. Smart agents and fog computing for smart city applications. In: *International Conference on Smart Cities*. Springer. pp. 137–146. DOI: https://doi.org/10.1007/978-3-319-39595-1_14

Gokhale, P, Bhat, O and **Bhat, S.** 2018. Introduction to iot. *International Advanced Research Journal in Science, Engineering and Technology*, 5: 41–44.

Grasso, C, Raftopoulos, R and **Schembra, G.** 2022. Smart zero-touch management of uav-based edge network. *IEEE Transactions on Network and Service Management*. DOI: https://doi.org/10.1109/TNSM.2022.3160858

Grover, J, Jain, A, Singhal, S and **Yadav, A.** 2018. Real-time vanet applications using fog computing. In: *Proceedings of First International Conference on Smart System. Innovations and Computing*. Springer. pp. 683–691. DOI: https://doi.org/10.1007/978-981-10-5828-8_65

Hanumantharaju, R, Pradeep Kumar, D, Sowmya, B, Siddesh, G, Shreenath, K and **Srinivasa, K.** 2021. Enabling technologies for fog computing in healthcare 4.0: Challenges and future implications. In: *Fog Computing for Healthcare 4.0 Environments*. Springer. pp. 157–176. DOI: https://doi.org/10.1007/978-3-030-46197-3_7

Haseeb, K, Din, IU, Almogren, A, Ahmed, I and **Guizani, M.** 2021. Intelligent and secure edge-enabled computing model for sustainable cities using green internet of things. *Sustainable Cities and Society*, 68: 102779. DOI: https://doi.org/10.1016/j.scs.2021.102779

Kafy, AA, Rahman, MS, Islam, M, Al Rakib, A, Islam, MA, Khan, MHH, Sikdar, MS, Sarker, MHS, Mawa, J, Sattar, GS, et al. 2021. Prediction of seasonal urban thermal field variance index using machine learning algorithms in cumilla, bangladesh. *Sustainable Cities and Society*, 64: 102542. DOI: https://doi.org/10.1016/j.scs.2020.102542

Kai, K, Cong, W and **Tao, L.** 2016. Fog computing for vehicular ad-hoc networks: paradigms, scenarios, and issues. *The journal of China Universities of Posts and Telecommunications*, 23: 56–96. DOI: https://doi.org/10.1016/S1005-8885(16)60021-3

Karamoozian, A, Hafid, A and **Aboulhamid, EM.** 2019. On the fog-cloud cooperation: How fog computing can address latency concerns of iot applications. In: *2019 Fourth International Conference on Fog and Mobile Edge Computing (FMEC)*. IEEE. pp. 166–172. DOI: https://doi.org/10.1109/FMEC.2019.8795320

Khan, SU. 2016. The curious case of distributed systems and continuous computing. *IT Professional*, 18: 4–7. DOI: https://doi.org/10.1109/MITP.2016.24

Kishor, A, Chakraborty, C and **Jeberson, W.** 2021. Reinforcement learning for medical information processing over heterogeneous networks. *Multimedia Tools and Applications*, 80: 23983–24004. DOI: https://doi.org/10.1007/s11042-021-10840-0

Kök, İ, Okay, FY and **Özdemir, S.** 2022. Fogai: An ai-supported fog controller for next generation iot. *Internet of Things*, 19: 100572. DOI: https://doi.org/10.1016/j.iot.2022.100572

Kusuma, G. A survey on secure fog-computing infrastructure for internet of vehicles.

Lai, CS, Jia, Y, Dong, Z, Wang, D, Tao, Y, Lai, QH, Wong, RT, Zobaa, AF, Wu, R and **Lai, LL.** 2020. A review of technical standards for smart cities. *Clean Technologies*, 2: 290–310. DOI: https://doi.org/10.3390/cleantechnol2030019

Laroui, M, Nour, B, Moungla, H, Cherif, MA, Afifi, H and **Guizani, M.** 2021. Edge and fog computing for iot: A survey on current research activities & future directions. *Computer Communications*, 180: 210–231. DOI: https://doi.org/10.1016/j.comcom.2021.09.003

Leite, J, Martins, PS and **Ursini, EL.** 2019. Planning of adhoc and iot networks under emergency mode of operation. In: *2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*. IEEE. pp. 1071–1080. DOI: https://doi.org/10.1109/IEMCON.2019.8936196

Li, J, Shen, X, Chen, L, Van, DP, Ou, J, Wosinska, L and **Chen, J.** 2019. Service migration in fog computing enabled cellular networks to support real-time vehicular communications. *IEEE Access*, 7: 13704–13714. DOI: https://doi.org/10.1109/ACCESS.2019.2893571

Liyanage, M, Pham, QV, Dev, K, Bhattacharya, S, Maddikunta, PKR, Gadekallu, TR and **Yenduri, G.** 2022. A survey on zero touch network and service (zsm) management for 5g and beyond networks. *Journal of Network and Computer Applications*, 103362. DOI: https://doi.org/10.1016/j.jnca.2022.103362

Logvinov, O, Kraemer, B, Adams, C, Heiles, J, Stuebing, G, Nielsen, M and **Mancuso, B.** 2016. Standard for an architectural framework for the internet of things (iot) ieee p2413. IEEE-P2413 Working Group. Technical Report.

Lopes, MM, Higashino, WA, Capretz, MA and **Bittencourt, LF.** 2017. Myifogsim: A simulator for virtual machine migration in fog computing. In: *Companion Proceedings of the 10th International Conference on Utility and Cloud Computing*. pp. 47–52. DOI: https://doi.org/10.1145/3147234.3148101

Machado, C and **Westphall, CM.** 2021. Blockchain incentivized data forwarding in manets: Strategies and challenges. *Ad Hoc Networks*, 110: 102321. DOI: https://doi.org/10.1016/j.adhoc.2020.102321

Maharjan, B, Li, J, Alian, S and **Bai, Y.** 2019. A human-centric cloud and fogassisted iot platform for disaster management. In: *2019 7th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering*

(MobileCloud). IEEE. pp. 8–15. DOI: https://doi.org/10.1109/MobileCloud.2019.00009

Mohammed, MA, Ibrahim, DA, Abdulkareem, KH, et al. 2021. Bioinspired robotics enabled schemes in blockchain-fog-cloud assisted iomt environment. *Journal of King Saud University-Computer and Information Sciences*.

Muneeb, M, Ko, KM and **Park, YH.** 2021. A fog computing architecture with multi-layer for computing-intensive iot applications. *Applied Sciences*, 11: 11585. DOI: https://doi.org/10.3390/app112411585

Nagarajan, SM, Deverajan, GG, Chatterjee, P, Alnumay, W, Ghosh, U. 2021. Effective task scheduling algorithm with deep learning for internet of health things (ioht) in sustainable smart cities. *Sustainable Cities and Society*, 71: 102945. DOI: https://doi.org/10.1016/j.scs.2021.102945

Naha, RK, Garg, S, Georgakopoulos, D, Jayaraman, PP, Gao, L, Xiang, Y and **Ranjan, R.** 2018. Fog computing: Survey of trends, architectures, requirements, and research directions. *IEEE access*, 6: 47980–48009. DOI: https://doi.org/10.1109/ACCESS.2018.2866491

Nair, GS, Devika, P, Jyothisree, K, Giriraj, N and **Sai Shibu, NB.** 2021. Architecture, concept and algorithm for data analytics based zero touch waste management in smart cities. In: *2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC)*. IEEE. pp. 851–856. DOI: https://doi.org/10.1109/ICESC51422.2021.9532723

Naous, T, Itani, M, Awad, M and **Sharafeddine, S.** 2023. Reinforcement learning in the sky: A survey on enabling intelligence in ntn-based communications. *IEEE Access*. DOI: https://doi.org/10.1109/ACCESS.2023.3236801

Pathan, ASK. 2016. Security of self-organizing networks: MANET, WSN, WMN, VANET. CRC press. DOI: https://doi.org/10.1201/EBK1439819197

Peña, MAL and **Fernández, IM.** 2019. Sat-iot: An architectural model for a high-performance fog/edge/cloud iot platform. In: *2019 IEEE 5th World Forum on Internet of Things* (WF-IoT). IEEE. pp. 633–638.

Pereira, J, Ricardo, L, Luís, M, Senna, C and **Sargento, S.** 2019. Assessing the reliability of fog computing for smart mobility applications in vanets. *Future Generation Computer Systems*, 94: 317–332. DOI: https://doi.org/10.1016/j.future.2018.11.043

Ramírez-Moreno, MA, Keshtkar, S, Padilla-Reyes, DA, Ramos-López, E, García-Martínez, M, Hernández-Luna, MC, Mogro, AE, Mahlknecht, J, Huertas, JI, Peimbert-García, RE, et al. 2021. Sensors for sustainable smart cities: A review. *Applied Sciences*, 11: 8198. DOI: https://doi.org/10.3390/app11178198

Rayes, A and **Salam, S.** 2019. Internet of things (iot) overview. In: *Internet of Things from hype to reality*. Springer. pp. 1–35. DOI: https://doi.org/10.1007/978-3-319-99516-8_1

Rejeb, A, Rejeb, K, Simske, S, Treiblmaier, H and **Zailani, S.** 2022. The big picture on the internet of things and the smart city: a review of what we know and what we need to know. *Internet of Things*, 19: 100565. DOI: https://doi.org/10.1016/j.iot.2022.100565

Rezazadeh, F, Chergui, H, Alonso, L and **Verikoukis, C.** 2020. Continuous multi-objective zero-touch network slicing via twin delayed ddpg and openai gym. In: *GLOBECOM 2020–2020 IEEE Global Communications Conference*. IEEE. pp. 1–6. DOI: https://doi.org/10.1109/GLOBECOM42002.2020.9322237

Romanovs, A, Sultanovs, E, Buss, E, Merkuryev, Y and **Majore, G.** 2021. Challenges and solutions for resilient telemedicine services. In: *2020 IEEE 8th Workshop on Advances in Information, Electronic and Electrical Engineering* (AIEEE). IEEE. pp. 1–7. DOI: https://doi.org/10.1109/AIEEE51419.2021.9435776

Salman, O, Elhajj, I, Chehab, A and **Kayssi, A.** 2018. Iot survey: An sdn and fog computing perspective. *Computer Networks*, 143: 221–246. DOI: https://doi.org/10.1016/j.comnet.2018.07.020

Sarangi, AK, Mohapatra, AG, Mishra, TC and **Keswani, B.** 2021. Healthcare 4.0: A voyage of fog computing with iot, cloud computing, big data, and machine learning. In: *Fog Computing for Healthcare 4.0 Environments*. Springer. pp. 177–210. DOI: https://doi.org/10.1007/978-3-030-46197-3_8

Saroa, MK and **Aron, R.** 2018. Fog computing and its role in development of smart applications. In: *2018 IEEE Intl Conf on Parallel & Distributed Processing with Applications, Ubiquitous Computing & Communications, Big Data & Cloud Computing, Social Computing & Networking, Sustainable Computing & Communications (ISPA/IUCC/BDCloud/SocialCom/SustainCom)*. IEEE. pp. 1120–1127. DOI: https://doi.org/10.1109/BDCloud.2018.00166

Singh, PK, Nandi, SK and **Nandi, S.** 2019. A tutorial survey on vehicular communication state of the art, and future research directions. *Vehicular Communications*, 18: 100164. DOI: https://doi.org/10.1016/j.vehcom.2019.100164

Sultan, SA, Asgarnezhad, R, Hussein, BA, Sultan, MA and **Mohsen, HM.** 2021. Fog computing based on the transmitters and receivers near these devices according to the geographical area. where the resources of these passive devices or the semi-passive devices close to them are utilized. *International Journal of Progressive Research in Science and Engineering*, 2: 140–147.

Taheri, J and **Deng, S.** 2020. Smart cities enabled by edge computing, wuhui chen, zhen zhang, baichuan liu. In: *Edge Computing: Models, Technologies and Application*. The Institution of Engineering and Technology (IET).

Tariq, N, Asim, M, Al-Obeidat, F, Zubair Farooqi, M, Baker, T, Hammoudeh, M and **Ghafir, I.** 2019. The security of big data in fog-enabled iot applications including blockchain: A survey. *Sensors*, 19: 1788. DOI: https://doi.org/10.3390/s19081788

Tseng, CL and **Lin, FJ.** 2018. Extending scalability of iot/m2m platforms with fog computing. In: *2018 IEEE 4thWorld Forum on Internet of Things (WF-IoT)*. IEEE. pp. 825–830. DOI: https://doi.org/10.1109/WF-IoT.2018.8355143

Ullah, A, Yao, X, Shaheen, S and **Ning, H.** 2019. Advances in position based routing towards its enabled fog-oriented vanet–a survey. *IEEE Transactions on Intelligent Transportation Systems*, 21: 828–840. DOI: https://doi.org/10.1109/TITS.2019.2893067

Vaquero, LM and **Rodero-Merino, L.** 2014. Finding your way in the fog: Towards a comprehensive definition of fog computing. *ACM SIGCOMM computer communication Review*, 44: 27–32. DOI: https://doi.org/10.1145/2677046.2677052

Wagle, S and **Pecero, JE.** 2019. Efforts towards iot technical standardization. In: *International Conference on Ad-Hoc Networks and Wireless*. Springer. pp. 524–539. DOI: https://doi.org/10.1007/978-3-030-31831-4_36

Weisgrau, S. 1995. Issues in rural health: access, hospitals, and reform. *Health care financing review*, 17: 1.

Yannuzzi, M, van Lingen, F, Jain, A, Parellada, OL, Flores, MM, Carrera, D, Pérez, JL, Montero, D, Chacin, P, Corsaro, A, et al. 2017. A new era for cities with fog computing. *IEEE Internet Computing*, 21: 54–67. DOI: https://doi.org/10.1109/MIC.2017.25

Ye, H, Liang, L, Li, GY, Kim, J, Lu, L and **Wu, M.** 2018. Machine learning for vehicular networks: Recent advances and application examples. *IEEE vehicular technology magazine*, 13: 94–101. DOI: https://doi.org/10.1109/MVT.2018.2811185

Zahmatkesh, H and **Al-Turjman, F.** 2020. Fog computing for sustainable smart cities in the iot era: Caching techniques and enabling technologies-an overview. *Sustainable Cities and Society*, 59: 102139. DOI: https://doi.org/10.1016/j.scs.2020.102139

Zhang, W, Zhang, Z and **Chao, HC.** 2017. Cooperative fog computing for dealing with big data in the internet of vehicles: Architecture and hierarchical resource management. *IEEE Communications Magazine*, 55: 60–67.

Zhang Pettersson, S. 2022. Towards sustainable mobile networks: Ai for zero touch automated battery control. DOI: https://doi.org/10.1109/MCOM.2017.1700208

Zhu, X, Luo, Y, Liu, A, Bhuiyan, MZA and **Zhang, S.** 2020. Multiagent deep reinforcement learning for vehicular computation offloading in iot. *IEEE Internet of Things Journal*, 8: 9763–9773. DOI: https://doi.org/10.1109/JIOT.2020.3040768

TO CITE THIS ARTICLE:
Basheer, H and Itani, M. 2023. Zero Touch in Fog, IoT, and MANET for Enhanced Smart City Applications: A Survey. *Future Cities and Environment,* 9(1): 5, 1–19. DOI: https://doi.org/10.5334/fce.166

Submitted: 25 September 2022 **Accepted:** 14 March 2023 **Published:** 13 April 2023