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A Deployment Model for IoT Devices Based on Fog Computing for Data Management and Analysis

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Abstract

Instead of using cloud computing technology directly, IoT and Fog computing has introduced new data management methods that seem promising. Applications for real-time analytics are enabled by Fog computing. After integrating Fog computing technology into Internet of Things (IoT) applications, the system can respond in milliseconds. This paper presents literature reviews on some key areas of this research, for example, Fog computing models and the Internet of Things. This study's general methodology is based on a qualitative approach, specifically, an in-depth interview and a systematic literature review. The outcome will be a model that can manage and analyze IoT data for different IoT applications by identifying success factors associated with the implementation of Fog computing and IoT.

Keywords Fog Computing · IoT · Big Data · Smart Cities

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1 Introduction

Fog computing and the Internet of Things are two well-known Information and Communications Technology (ICT) theoretical paradigms that have gained popularity in recent years. The Internet of Things (IoT) enables interoperability between various items as well as context-sensitive deployment of its features. Cloud Computing has for quite some time been known as a worldview for Big Data storage and analytics. The perceived backend solution for managing massive data volumes and computations while addressing the challenges of all things being linked to continuous networks in the future is Cloud Computing [1].

Using a new concept known as "Fog computing," IoT data generated from various devices may be managed and examined at the edge. Moreover, Fog is similar to the cloud but closer to the edge. Hence, the use of Fog, enables applications and services to act before they are sent to the cloud, especially when it comes to data analysis and management [2]. In the context of the previous definition of IoT Fog computing, which may be seen as lowering latency and throughput while still providing security, a new paradigm known as Fog is necessary to suit the needs and limits related to the cloud.

Services in close-by network devices to the IoT devices are managed by Fog computing. But in terms of processing, network devices are comparatively inefficient resources in comparison to the cloud, which makes it challenging for a single network device, to manage numerous services. Fog computing is hence appropriate for locally dispersed, processing with limited capacity as opposed to centralized processing with a huge capacity. Therefore, it's important to deploy the service in the right place while taking into account the network equipment's computational capabilities [3]. When processing a service in a Fog computing environment rather than a service processing environment in the cloud, the service response time is significantly decreased. Traditional IoT architectures are used to connect the sensing devices to the Internet, which then sends the data they produce to a cloud resource for processing [4]. For situations where, stringent latency is not a concern, this solution works effectively. The cloud is not the best resource for applications that need instantaneous replies[5]. Moreover, no study quantifies the impact of all success variables on smart cities adopting Fog computing for their data management and analysis [6, 7].

For successful implementation, this study created a conceptual model that considers the requirement for a fog computing model and the internet of things in smart cities. The proposed framework aims to highlight the factors that are necessary for its successful implementation, using qualitative data analysis.

2 Related Work

The previous study has reported the use of Fog with IoT Models for different applications and scenarios [8–10]. This study presents a model for IoT devices and applications by combining the advantages of Fog computing and IoT. Table 1 shows the IoT-based Fog, computing models.

The majority of earlier studies looked into each of these areas separately as implementation success factors or/and models: business, infrastructure, management, and policy. Additionally, it showed how little empirical research has been done on the implementation success criteria for Fog computing and IoT. This underscores the need for more research

Table 1 IoT-Fog models

Approach/Model Proposed	Descriptions	Authors
Smart Building	They developed the notion of Fog and in some way supplied a border control and integrated worldview of the Fog. They also described the technological developments of Fog at various rates.	[11]
Mobile Fog	They present mobile Fog as the appropriate software system for designing applications in the Fog to obtain the possible efficiency and latency benefits of Fog computing.	[12]
Spatio-temporal	They implemented an information model for Spatio-temporal analysis for large-scale camera network situational awareness.	[13]
Heterogeneous resource architecture	They developed a heterogeneous shared resources architectural design between mobile devices that refers to certain concepts of Fog computing.	[14]
Smart communication	The intelligent gateways based on Fog computing are part of the smart communication paradigm put forth to lessen the burden of the cloud. a non-trivial cloud extension based on the Fog computing paradigm.	[15]
Web optimization	They recommend web optimization with the background of Fog computing, leveraging new methods accessible for previous techniques at the Fog nodes, thus enhancing the efficiency of users on the web page.	[16]
Distributed load balancing algorithm	They use a plausible smart city model to conduct several evaluations about the causes of technological diversity	[7]

to be conducted in addition to the empirical studies that examined the background factors that influenced the adoption of Fog computing and other IoT-focused technologies. It offers thorough empirical research that is holistic and all-encompassing in what is known as an implementation success model.

3 Background

3.1 Internet of Things

The Internet of Things (IoT) consists of interconnected computer technology networks with smart objects and with unique mechanical identities that are intended to send and receive data without the intervention of humans [17, 18]. IoT has several different players and has gained ample popularity in smart city application areas; smart homes and other smart applications often form part of a broader picture of the future IoT ecosystem [19]. Moreover, end-users in the private and business realms also gain valuable skills in managing smart IoT devices and applications. A mix of related technical methods and principles such as cloud computing forecasts more potential, Digital Internet, Big Data, Robotics, and Semantic IoT Expansion [20]. The related concepts have created greater synergies and support the maturity of IoT and its future expansion [21]. It is hoped that IoT will be able to build a bridge between smart environments and the large test scale, using network sensors and simulating day-to-day experience to create smarter innovations. The exciting next major step in IoT evolution is a synergy forum for all efforts to achieve innovation and domestic development [22, 23].

3.2 Cloud Computing

One of the most important topics in both academic and commercial science is cloud computing. Cloud computing consists of hundreds or thousands of computers and servers that provide enterprise computing services or remote data centers on the Internet [24]. Cloud computing is defined in various ways. Ercan [25], has characterized the cloud as a service that gives IT capabilities with tremendous growth potential to a wide range of external entities, such as clients servicing through Online services [26]. This idea can also be defined as a network that involves massively the capabilities of a scalable IT that will be sent to external customers based on Internet Technology. The on-demand service model is provided when cloud computing is used, users can use the service as they require, and only pay for what they have used [26]. Cloud Computing manages data in terms of storage and accessibility, in which the device's actual location that's where it secretly offers support to end customers [27]. Sultan [28], shows that the cloud does not have a specific meaning, but researchers prefer the following definition, this shows it as a cluster of distributed computers with the ability to provide on-demand services and services on certain network types. Previous studies have documented some problems and limitations regarding the implementation of cloud computing, which include: data segregation, data deletion, offline cloud, privacy, data lock-in, data confidentiality and suitability, network, software licensing, protection, and control [29]. In addition, the need for high-speed internet requires high rates of latency and security, etc [30].

3.3 Fog Computing

It is easy to assess the necessity of proposing a new IT strategy in light of current trends in data volume and velocity, and cloud computing limits. In this case, Cisco has recommended the cutting-edge idea of Fog computing [31]. A distributed processing system called Fog computing will support billions of (IoT) devices. Fog computing is also thought of as a paradigm in which the execution of collected data and software happens at the network edge rather than totally in the cloud, allowing services to be segregated from the public cloud and placed closer to the end user [32]. The Fog supplies the cloud with services and data as a streamlined exchange medium, and it is positioned in hierarchical structures beneath the cloud [33]. Since Fog computing occurs outside of the cloud, cloud administrations, such as statistics, storage, workloads, applications, and vast quantities of information, can be distributed in a genuinely communicated way at any edge of the network [34]. By managing data across different networks, Fog computing incorporates cloud administration with the center to transform the server into a dispersed cloud for clients. Fog conveys figures from the middle to the edge of the device, as they were [35] as shown in Fig. 1. It might simply also be a term for Edge registration in this situation. Edge Computing moves computing processes, data, and administrations to the smart ends of a network far from centralized hubs. It makes it possible for data processing to carry on at the network's edge. This strategy calls for the utilization of resources that might not always be connected to a system, like mobile phones, tablets, and sensors [36]. Previous studies documented the features of Fog computing [37, 38]. Fog computing features include edge position, position knowledge, low latency, geographic distribution, distributed computing and storage resources, a higher

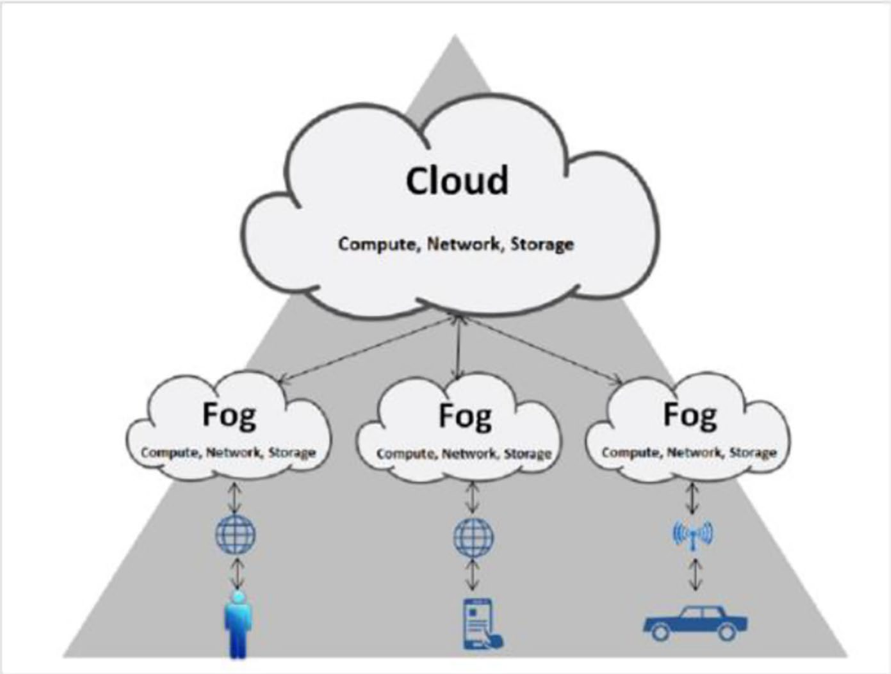

Fig. 1 Fog computing architecture

Table 2 Fog computing characteristics

Characteristic	Descriptions	Authors
Location awareness, edge location, and low latency	The primary benefit of Fog computing is that assets are indeed located at the edge of networks, which puts them very near to data sources and users.	[40]
Support for mobility	Even the communication mechanisms must be decoupled from the software applications operating in the Fog	[16, 41]
Geographical distribution	A Fog's resources are naturally dispersed throughout a wider geographic area. This enables the implementation of services that consider this feature to be a competitive advantage.	[42]
Resources for distributed computing and storage	The Fog is a collection of resource pools made up of numerous virtualized critical components that are dispersed over the network's perimeter.	[43]
Significantly more nodes	Every node's computational capability is lower than the sum of all nodes since the Fog aims to reduce latency.	[44, 45]

number of nodes, Support for mobile devices, real-time interaction, flexibility, networking, and teamwork [39]. An overview of the Fog computing features is given in Table 2.

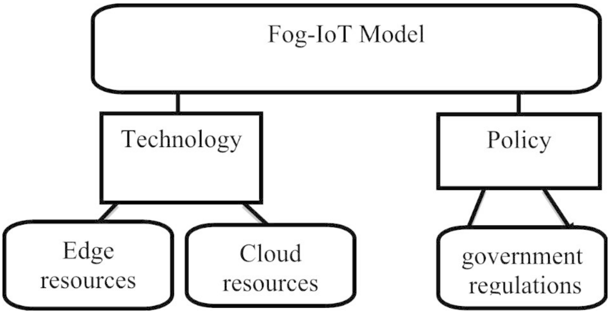

Fig. 2 The conceptual model of the research

4 The Theoretical Model

From IoT and Fog computing literature, a theoretical model has been created by fusing the Multiple-Open-Platform model [46] with IoT factor models [47]. According to the IoT paradigm, it is crucial to comprehend several components to understand how software and hardware work [48]. The second theoretical foundation is a network for public service called Multiple-Open-Platform [49]. A road map for the efficient implementation of the technological and societal components of Fog computing is provided by the two models, the Multiple-Open-Platform model and the IoT model. Figure 2 shows the conceptual model used for this study.

5 Method

The methodological framework is designed with close attention to the objectives of this study and their supporting justifications to identify success factors and their relation to business, infrastructure, technical expertise, managerial, and government policy. The overall framework employed by this study is based on a qualitative approach, specifically, a systematic literature review and in-depth interviews. The population size of the technical experts for Fog computing is indefinite and in-depth interviews are a qualitative research method. Therefore, purposive sampling is to be employed as a sampling method [50]. This implies that the choice of the sample size is not based on any population size, but rather essentially attends to the purpose of this study. The technical experts interviewed are chosen because they have the requisite knowledge and understanding of the interview questions.

The data structure working in the Fog node is shown in Fig. 3. An extra security layer between physical devices and the data center is provided by IoT nodes and gateways. The IoT node and gateway are the core components of the IoT system and architecture because they facilitate data transfer to the cloud and close the communication gap between the various devices on the network. In the case of a Fog node, the data which is coming from the IoT nodes are then stacked with the IoT node id, this is a type of data structure that is trying to be built at the Fog as shown in Fig. 3. Moreover, the data will come from different IoT nodes and each packet of the IoT node will be aggregated at the Fog. The data will be processed using standard machine-learning techniques to generate the analytics model. In addition, the use of feature reeducation Principal component analysis (PCA) can help us to identify patterns in data based on the correlation between features. The model classification SVM will be used to reduce the error and enhance the proposed model.

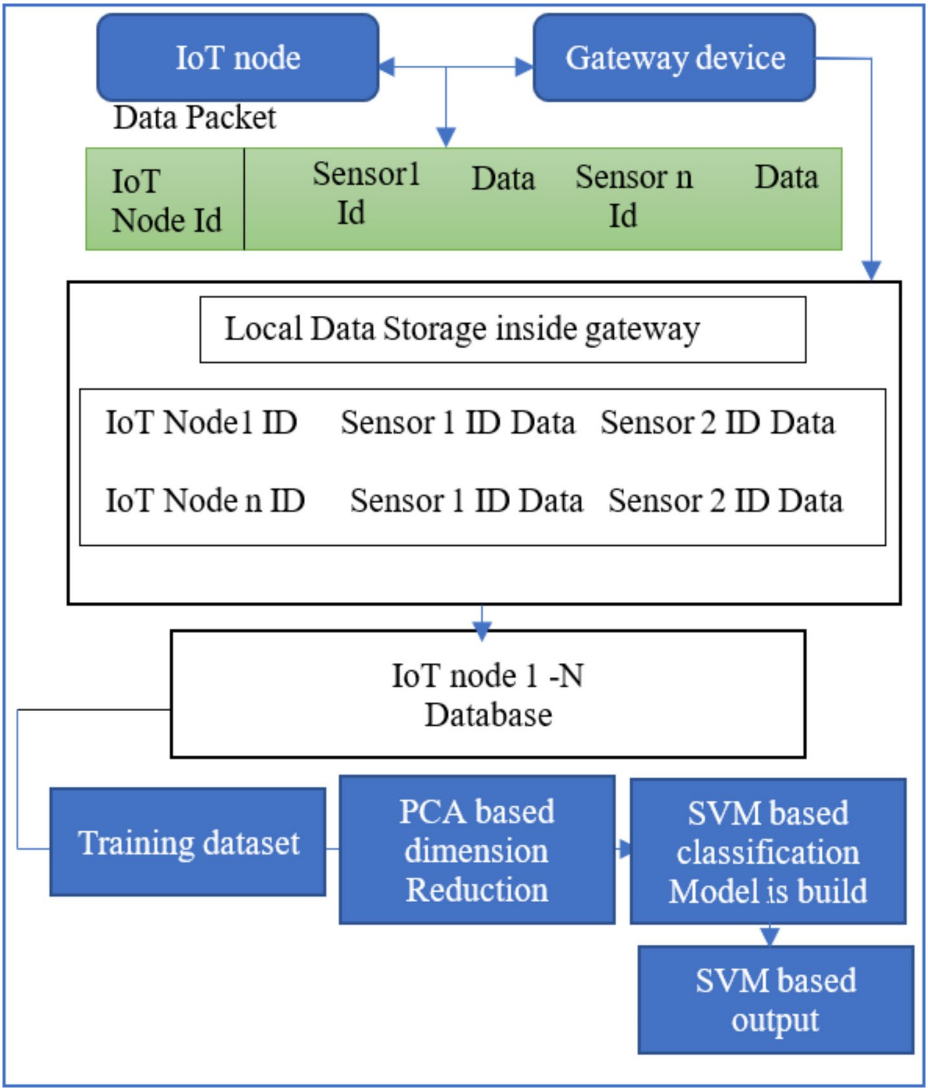

Fig. 3 A data structure in the Fog node

6 Results and Discussions

6.1 Architectural Model

The model is proposed based on the findings of the qualitative data analysis from the in-depth interviews. To fix the issues with IoT and cloud computing's convergence in terms of data handling, the architecture of the IoT model is built on Fog computing and supports a variety of IoT devices and applications. An end-to-end solution is provided that will allow data to be analyzed while retaining system protection as well as IoT functionality for smart

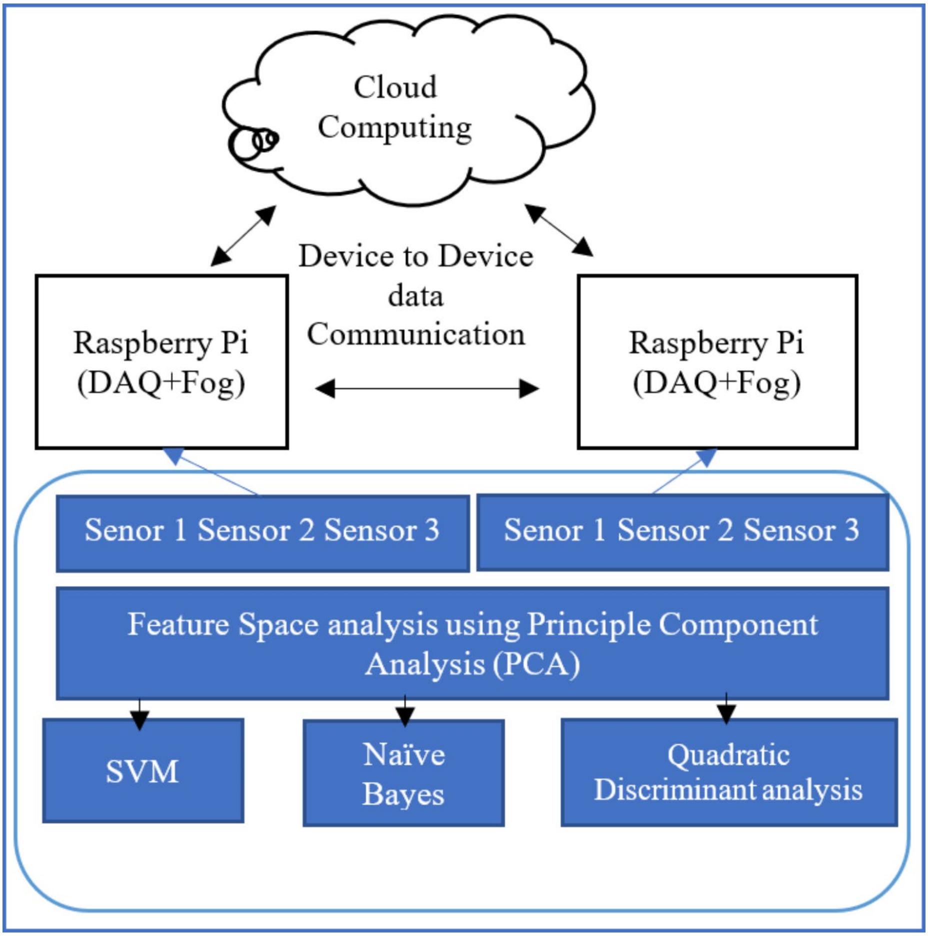

Fig. 4 Fog Node-Based Data Analytics Model

devices to connect with both cloud storage and with one another while providing quality services. Figure 4 shows the standard technique used to build the Fog which will be by using Raspberry Pi that can work as a Data acquisition and also as a Fog at the same time due to the strong memory they have and the processing capability. To determine the directions of maximum variance, principal component analysis maps high-dimensional data into a new subspace with the same number of dimensions as the original subspace. In Fog-based mobile edge computing, spam detection will be performed using naive Bayes methods, and SVM intrusion detection classification can be used to identify intrusions.

6.2 Findings from the Qualitative Data Analysis

The contributory features that allowed for the implementation model for Fog computing and IoT in smart cities emerged based on the data analysis from the literature review and the in-depth interview, the emerged conceptions are grouped into themes and sub-themes in

Table 3 Summary of the Fog implementation success factors

Factor	Element	Sub-themes
Technology	Resources	Fog resources
		Cloud resources
	Hardware	Hardware equipment
		Sensors objects
	Software	Machine learning
		Management system
Government policy	Technology investors	Provision of platform

line with the thematic analysis approach adopted for this study. Table 3 presents the summary of the implementation success factors, their respective elements, and corresponding sub-themes as the general findings of the qualitative data analysis.

7 Conclusion

Integrating IoT technologies and Fog computing brings new methodologies that allow IoT solutions to be reviewed and controlled before they are transmitted to the cloud, Data security is verified before being sent to the cloud, enabling data analysis at the edge of computing. Fog computing allows businesses to act on both protected and available data, resulting in a great advantage for the enterprise. Success factors with elements related to the implementation of Fog computing and IoT have been identified in this study, a more in-depth investigation with a broader search and subsequent literature analysis may provide possible success variables that have not been explored in this study.

Author Contribution All authors contributed to the study's conception. Conceptualization: WN,HN,HN,AQ; Methodology: WN, HN, HN; Investigation: WN, HN,AQ; Writing: WN,HN,HN,AQ Review & editing: WN,HN,HN.

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Data Availability No data was used for the research described in the article and Code does not apply to this paper.

Declarations

Conflict of Interest We have no conflicts of interest to disclose and all authors have checked the manuscript and have agreed to the submission.

Research Involving Human Participants and/or Animals This article does not contain any studies with human participants or animals performed by any of the authors.

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