SMART FOG – A COLLABORATIVE APPROACH TO SHARE COMPUTATIONAL POWER OF FOG DEVICES FOR FOG COMPUTING IN SMART CITY IoT NETWORK

स्मार्ट फ़ॉग - स्मार्ट सिटी आईओटी नेटवर्क में फ़ॉग कंप्यूटिंग के लिए फ़ॉग उपकरणों की कम्प्यूटेशनल शक्ति साझा करने के लिए एक सहयोगात्मक दृष्टिकोण

A Thesis

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by

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PREFACE

Smart cities have emerged as a solution to enhance services and quality of life for residents and visitors. These cities have made significant progress in optimizing resource utilization, promoting environmental protection, improving infrastructure operations and maintenance, and strengthening safety and security measures. Achieving these improvements requires the implementation of new and existing technologies, as well as the application of optimization techniques. Among the technologies supporting smart city applications, the Internet of Things, FOG computing, and cloud computing play vital roles. Integrating these three technologies into a single system, known as the integrated IoT-Fog-Cloud system, offers a sophisticated platform for developing and managing various smart city applications. By leveraging the strengths of IoT gadgets, FOG nodes, and cloud services, this platform enables applications to deliver optimal functionality and performance. The integrated system opens up numerous opportunities for enhancing applications across sectors such as energy, transportation, healthcare, and more. This research work focuses on designing an improvised SMART FOG system, which the key emphasis of the study.

Outline of the Thesis:

The entire research work is divided into six chapters as discussed. The chapterization contains the overview of the proposed SMART FOG protocol-based technique, implementation challenges, task allocation, scheduling techniques, fault tolerance mechanisms, literature review of different authors, result analysis/testing, performance evaluation, and conclusion.

- **Chapter - 1 Introduction:** Serves as a foundation for the research work by highlighting the need for the study. It accomplishes this by referencing various articles and analyzing surveys to establish a solid base for the proposed research. To clarify the background concepts of fog computing, different terminologies related to fog computing are defined and explained. This ensures that readers have a clear understanding of the key terms and concepts associated with the research topic. The chapter also provides an overview of the proposed SMART FOG protocol-based technique. It explains the core features and functionality of

the technique, highlighting how it differs from existing approaches. Additionally, a comparative study is conducted to compare the proposed technique with other relevant methods in the field. This comparison helps to establish the unique benefits and advantages of the SMART FOG protocol-based technique. By encompassing these elements, the first chapter sets the stage for the research work, presenting the need for the study, providing a solid base through article references and survey analysis, clarifying fog computing concepts, and introducing the proposed SMART FOG protocol-based technique along with its comparative study.

- **Chapter -2 Literature Review:** Focuses on reviewing past studies conducted in the research area. It involves examining a broad range of previously completed research projects and providing a comprehensive background of other relevant research works. These sources of literature include journals, articles, research papers, and reputable platforms such as the OpenFog Consortium, IEEE conferences and journals, Springer publications, and online fog computing articles and resources. By conducting this review, the chapter aims to gather existing knowledge, identify gaps in the research field, and build upon the work that has already been done. It provides a critical analysis and synthesis of the literature, highlighting key findings, methodologies, and advancements in fog computing and related domains. The review of the literature serves several purposes. Firstly, it helps to establish the current state of the research area, providing a context for the proposed study. Secondly, it helps the researcher identify research gaps or areas that require further exploration. By examining the existing literature, the chapter also highlights the strengths and weaknesses of previous approaches, leading to insights and inspiration for the proposed research. The sources of literature mentioned, such as the OpenFog Consortium, IEEE, Springer, and online fog computing articles and resources, represent reputable and authoritative platforms in the field. By consulting these sources, the chapter ensures a comprehensive and reliable review of the existing literature, contributing to the overall credibility and validity of the research project.

- **Chapter -3 Research Methodology:** This is dedicated to describing the methodology used in the research project. It primarily focuses on the architecture of the proposed system, including the use of block diagrams to visualize the system's structure. The chapter provides a detailed explanation of the different layers within the architecture, highlighting their functions and interactions. In addition to the system architecture, the chapter also explores the various technologies employed in the implementation of the proposed system. It delves into the specifics of these technologies, discussing their relevance and suitability for the project. The methodology chapter also outlines the research methods employed in the study. It mentions the use of questionnaires or surveys to gather data and insights from relevant stakeholders or experts in the field. These methods help in understanding the requirements, challenges, and expectations associated with the proposed system. By gathering feedback through questionnaires, the research project can align its objectives with the needs of the intended users or beneficiaries. Furthermore, the chapter addresses any gaps or open challenges that were identified during the literature review. It highlights how these gaps are addressed or resolved through the proposed research. The focus is on designing and developing the proposed system to bridge these gaps and overcome challenges identified in previous studies.

- **Chapter - 4 SMART FOG-based Technique:** Focuses on the implementation of the proposed system. The chapter discusses the total work done in the system and outlines the next steps and milestones to be achieved. It also addresses the challenges encountered during the selection of communication protocols and security measures for each layer of communication. The sharing of computational power between IoT devices and fog devices is identified as a challenging aspect, and an improvised method is proposed to enable this sharing. The proposed SMART FOG protocol-based technique aims to execute tasks in the fog environment to avoid latency issues associated with sending requests to cloud centers.

- **Chapter – 5 Allocation and Scheduling of Computational Power:** The focus is on the allocation and scheduling of computational resources shared with IoT devices. The chapter explores different techniques of resource allocation and scheduling, identifying the most efficient ones suitable for fog computing. The current work is tested according to the proposed system, and the results are evaluated to meet the objectives of the research. The evaluation specifically assesses the impact of the proposed work on latency issues in the existing system. Testing and evaluation are crucial for validating the hypothesis, which centers around implementing the SMART FOG protocol-based technique to create a fog environment that shares computational power with IoT devices.

- **Chapter – 6 Conclusion and Future Work:** Provides a summary of the research work and its outcomes in comparison to the expected results defined during the design phase. A detailed analysis is conducted to project future possibilities and enhancements to the system resulting from the study. The chapter also highlights key challenges and issues that warrant further investigation for future development. This chapter serves as a conclusion to the research, summarizing its findings and suggesting avenues for future research and improvement.

In conclusion, based on the evaluation of various accuracy parameters, it can be inferred that the MLP classifier and Logistic Regression are the most suitable classification algorithms for resource allocation and task offloading in a SMART FOG environment. These classifiers consistently outperform the others and demonstrate their effectiveness in achieving accurate and reliable results.

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LIST OF ABBRIVATIONS

ACK	:	Acknowledgment
AMQP	:	Advanced Message Queuing Protocol
ANN	:	Artificial Neural Networks
CCTV	:	Closed-Circuit Television
CoAP	:	Constrained Application Protocol
CON	:	Confirmable Message
CPU	:	Central Processing Unit
CSP	:	Cloud Service Providers
DCPS	:	Data-Centric Publish-Subscribe
DDS	:	Data Distribution Service
DLRL	:	Data Local Reconstruction Layer
DOTS	:	Dynamic Optimization of Time Sequences
EDA	:	Estimation of Distribution Algorithm
EDF	:	Earliest Deadline First
LFC	:	Least Slack Time
FCFS	:	First-Come, First-Served
FLPSO	:	Fuzzy Logic and Particle Swarm Optimization
FPFTS	:	Fuzzy-Possibilistic Fuzzy Time Series
H2H	:	Human-to-Human
HAN	:	Home-Area Network
HH	:	Hybrid Heuristic
HTP	:	Hypertext Transfer Protocol
IACO	:	Improved Ant Colony Optimization
ICT	:	Information and Communications Technology
IEEE	:	Institute of Electrical and Electronics Engineers
ILP	:	Integer Linear Programming
IoE	:	Internet of Energy
IoMT	:	Internet of Medical Things
IoP	:	Internet of People
IoS	:	Internet of Things

IP	:	Internet Protocol
IPSO	:	Improved Particle Swarm Optimization
IT	:	Information Technology
ITS	:	Intelligent Transportation System
KNN	:	K-Nearest Neighbor
LAN	:	Local Area Network
LoRaWAN	:	WAN Long Range Wide Area Network
LR	:	Logistic Regression
LWM2M	:	Light-Weight Machine-To-Machine Communication
M2M	:	Machine-to-Machine
MAPE-K	:	Monitor, Analyze, Plan, Execute, and Knowledge
MCC	:	Matthews Correlation Coefficient
MCCV	:	Minimum Critical-Cycle Variance
MEC	:	Mobile Edge Computing
MILP	:	Mixed Integer Linear Programming
MIPs	:	Million Instructions Per Seconds
ML	:	Machine Learning
MLP	:	Multilayer Perceptron
MQTT	:	Message Queuing Telemetry Transport
MTC	:	Machine Type Communication
NCA	:	Network Computing and Applications
NFC	:	Near Field Communication
NFV	:	Network Function Virtualization
NLP	:	Natural Language Processing
NON	:	Non-confirmable
PERA	:	Packetized Ensemble Resource Allocation
PRC	:	Precision-Recall Curve
PTPN	:	Preemptive Task Priority Network
PTZ	:	Pan-Tilt-Zoom
QoS	:	Quality of Service
RFID	:	Radio Frequency Identification

RR	:	Round Robin
RST	:	Representational State Transfer
SC	:	Smart Cities
SDN	:	Software-Defined Networking
SEM	:	Structural Equation Modelling
SG	:	Smart Grid
SIoT	:	Social Internet of Things
SJF	:	Shortest Job First
SLAs	:	Service Level Agreements
SLR	:	Systematic Literature Review
SVM	:	Support Vector Machine
TCP/ IP	:	Transmission Control Protocol and Internet Protocol
TIPS	:	Time-Invariant Power Scheduling
TLS	:	Transport Layer Security
TN	:	True Negative
TP	:	True Positive
UDP	:	User Datagram Protocol
URL	:	Uniform Resource Locator
Wi-Fi	:	Wireless Fidelity
WRR	:	Weighted Round Robin
WSN	:	Wireless Sensor Networks
XMPP	:	Extensible Messaging and Presence Protocol