AES ENCRYPTION OF RESOURCE ALLOCATION FOR ULTRA-RELIABLE AND ENHANCED MOBILE BROADBAND IOT APPLICATIONS IN FOG NETWORK

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DECLARATION

This thesis is dedicated to:

The sake of Allah, my Creator

My great teacher, Mohammed (May Allah bless
and grant him), who taught us the purpose of life;

My great parents, Uncle and Aunt who lead me and support;

My beloved brothers and sisters and all family;

My friends who encourage and support me;

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ABSTRACT

The cloud computing paradigm has evolved toward the edge in recent years in order to give improved Quality of Service (QoS) to Internet of Things (IoT) devices. However, because fog network technology's resource capacity is limited, it's critical to efficiently connect IoT applications with demanding QoS requirements to the available network infrastructure. We design a joint user association and resource allocation problem in the fog network's downlink in aforementioned research, taking into account the ever-increasing demand for QoS standards imposed by Ultra-Reliable Low Latency Communications (URLLC) and Enhanced Mobile BroadBand (EMBB) services. First, we enforce the analytical framework using an Analytic Hierarchy Process (AHP) to assess the priority of different QoS requirements of heterogeneous IoT applications at the fog network. We then create a two-sided matching game using the AHP to establish a solid connection between the fog network architecture and IoT devices. We next encrypt the data using the Advanced Encryption Standard (AES) technique to safeguard it against theft and misuse.

ABSTRAK

Paradigma pengkomputeran awan telah berkembang ke arah yang terbaik dalam beberapa tahun kebelakangan ini untuk memberikan Kualiti Perkhidmatan (QoS) yang lebih baik kepada peranti Internet Perkara (IoT). Walau bagaimanapun, kerana kapasiti sumber teknologi rangkaian kabus adalah terhad, adalah penting untuk menyambungkan aplikasi IoT dengan cekap dengan keperluan QoS yang menuntut kepada infrastruktur rangkaian yang tersedia. Kami mereka bentuk persatuan pengguna bersama dan masalah peruntukan sumber dalam pautan ke bawah rangkaian kabus dalam penyelidikan yang dinyatakan di atas, dengan mengambil kira permintaan yang semakin meningkat untuk standard QoS yang dikenakan oleh komunikasi kependaman rendah yang sangat boleh dipercayai dan perkhidmatan jalur lebar mudah alih yang meningkat. Pertama, kami menguatkuasakan rangka kerja analisis menggunakan Proses Hierarki Analitik untuk menilai keutamaan keperluan QoS berbeza bagi aplikasi IoT heterogen pada rangkaian kabus (AHP). Kami kemudian mencipta permainan padanan dua belah menggunakan AHP untuk mewujudkan sambungan yang kukuh antara seni bina rangkaian kabus dan peranti IoT. Kami seterusnya menyulitkan data menggunakan teknik Advanced Encryption Standard (AES) untuk melindunginya daripada kecurian dan penyalahgunaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AES	Advanced Encryption Standard
AHP	Analytic Hierarchy Process
AWT	Abstract Window Toolkit
BER	Bit Error Rate
CBAP	Configuration-Based Assignment And Packing
CFC	Cooperative Fog Computing
CR	Cognitive Radio
DES	Data Encryption Standard
EMBB	Enhanced Mobile Broadband
F-AP	Fog Access Point
FNC	Fog Network Coordinator
GRC	Global Resource Controller
GUI	Graphical User Interface
IDE	Integrated Development Environment
IoT	Internet of Things
JFC	Java Foundation Classes
JVM	Java Virtual Machine
ML	Machine Learning
QOS	Quality of Service
SR	Spectrum Reframing
URLLC	Ultra-Reliable Low Latency Communications

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Unlike its predecessor cloud, new Fog Network technology deemed essential considering IoT devices, enabling a wide range regarding intrinsic capabilities such as low latency, location awareness, mobility, & wireless access capability. Because regarding their proximity via IoT devices, gateway devices endure frequently regarded via exist part regarding Fog Network infrastructure. Fog devices automatically associate among IoT devices via provide cloud-like reinforcement via IoT applications at edge, thanks via some computational & storage capabilities mixed among networking functionalities. One regarding main goals regarding both IoT & Fog Network via offer end users among a high quality regarding service (QoS), which can exist accomplished through efficiently allocating limited network resources via heterogeneous IoT applications & services. As a result, end users use licenced either unlicensed spectrum considering a wide range regarding IoT applications, depending on availability regarding network resources & heterogeneous network interfaces. amount regarding real-time & non-real-time IoT traffic among different QoS needs constantly increasing as number regarding heterogeneous IoT devices grows dramatically. Table 1.1 shows usual QoS requirements considering Internet traffic from heterogeneous applications[1].

Table 1.1: Normal QoS Requirement for Internet Traffic[2].

Applications	Delay (s)	Throughput (Mbit/s)	BER
RTData	0.001 ~ 1	< 10	0
Image	1	2^{-10}	10^{-4}
Audio	0.25	0.064	$< 10^{-1}$
Video	0.25	100	10^{-2}

However, in Internet regarding Things, any newly found IoT devices in environment may necessitate entirely new IoT apps, each among its own set regarding resource requests & rapid resource deployment. As a result, QoS parameters in Table 1.1 have varying priorities. In certain instance, depending on application type, resource demand, & service priority, resource allocation must exist mapped via a specific IoT application. Ultra-Reliable Low Latency Communications (URLLC) service type applications, considering example, have a high need considering a tolerable bit error rate (BER) & an acceptable data delay. Enhanced Mobile Broadband (eMBB) service type applications in Fog networks generating real-time IoT traffics, on other hand, may have more strict bandwidth requirements than those considering timeliness & error-free communication[3].

1.2 Problem Statement

Most classic IoT resource allocation techniques, both distributed and centralised, are primarily concerned with IoT service or task providing without considering the application specific QoS parameters or the protection given to the data [2]. Therefore this project aims to build a resource allocation scheme based on the IOT QoS requirements and provides protection for the data by encryption.

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1.3 Objectives

The objectives of this project are as follows:

i. To build a two-sided matching game for establishing user associations and then allocating resources between Fog Network infrastructures and IoT devices based on QoS constraints.
ii. To provide protection by encrypting and decrypting the data with the application of AES Algorithm.
iii. To perform extensive numerical analysis to assess the suggested matching game's performance.

1.4 Scope of Study

The scope of this project is:

i. The development of two sided matching game that evaluates the application specific QoS requirements in Fog network technology.
ii. Utilizing Java Development Kit for the execution of the two sided matching game codes in the Eclipse run-time environment.
iii. The application of AES Algorithm for the encryption and decryption of data to be protected from theft and misuse.
iv. The evaluation of the performance used a graphical representation for comparison between our algorithm to the traditional Deferred Acceptance (DA) algorithm.

1.5 Contribution of the project

The main contribution of this project is that it provides a resource allocation method that evaluates the application specific QoS requirements which results in a more efficient resource allocation mechanism. Furthermore, it provides protection to the data from theft and misuse.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, first it introduces the resource allocation dilemma. Then it discusses cloud computing and Fog computing with a comparison between the two, then this chapter provide basic knowledge of URLLC and EMBB communications then it covers the QoS parameters and the resource allocation game theory, after which it describes the security provided to the network via Advanced Encryption Standard AES algorithm followed by brief introduction to Java and Finally this chapter includes the most recent and relevant literature surveys.

2.2 Resource Allocation

The process regarding allocating Time, Space, & Frequency domains in a spectrum known as resource allocation. goal regarding resource allocation in such systems via efficiently distribute limited available resources among terminals/clients in order via meet end users' service demands.

Among rapid expansion & evolution regarding communication networks & computer systems, resource allocation remains a major concern, since increased demand considering bandwidth-hungry and/or computation-intensive services necessitates higher quality regarding service. It must deal among a variety regarding new emerging system architectures, including cognitive networks, mesh networks, multihop networks, peer-to-peer networks, multistandard networks, cloud computing systems, & data centres. Distributed intelligence in a multitude regarding autonomously operating devices allows traditional centralised allocation mechanisms via exist replaced among fully distributed solutions[4].

2.3 Cloud Computing

Cloud computing a simple & straightforward prototype considering gaining access via a network on demand certain consists regarding a shared pool regarding programmable computer resources certain can exist provided extremely quickly among minimal administration effort. Cloud data centres endure enormous pools regarding easily accessible virtualized resources certain may exist dynamically reconfigured considering a scalable workload; aforementioned re-configurability advantageous considering pay-as-you-go cloud services. As shown in Figure 2.1 pay-as-you-go cost model allows customers via easily access remote computing resources & data management services while only being charged considering resources they utilise[5].

Figure 2.1: Cloud Computing Architecture

2.4 Fog Computing

Fog computing enables computation, storage, networking, & data management on network nodes in close proximity via IoT devices, bridging gap between cloud & end devices. While a result, computing, storage, networking, decision making, & data management occur not only on cloud, but also as data travels IoT-to-Cloud path (preferably close via IoT devices). In Intelligent Transportation Systems, considering example, GPS data can exist compressed at edge before being transmitted via cloud (ITS). "A horizontal system-level design certain spreads processing, storage, control, & networking capabilities closer via users along a cloud-to-thing continuum," according via Open Fog Consortium." In fog computing, a "horizontal" platform permits computing tasks via exist disseminated across platforms & industries, whereas a "vertical" platform encourages segregated applications. A vertical platform may exist well-suited via a single type regarding application (silo), but it ignores platform-to-platform interaction in other vertically focused platforms. Fog computing provides a flexible platform via fulfil data-driven needs regarding operators & consumers, in addition via facilitating a horizontal architecture. Fog computing designed via give Internet regarding Things a strong foundation. Figure 2.2 depicts the architecture regarding Fog Computing[6].

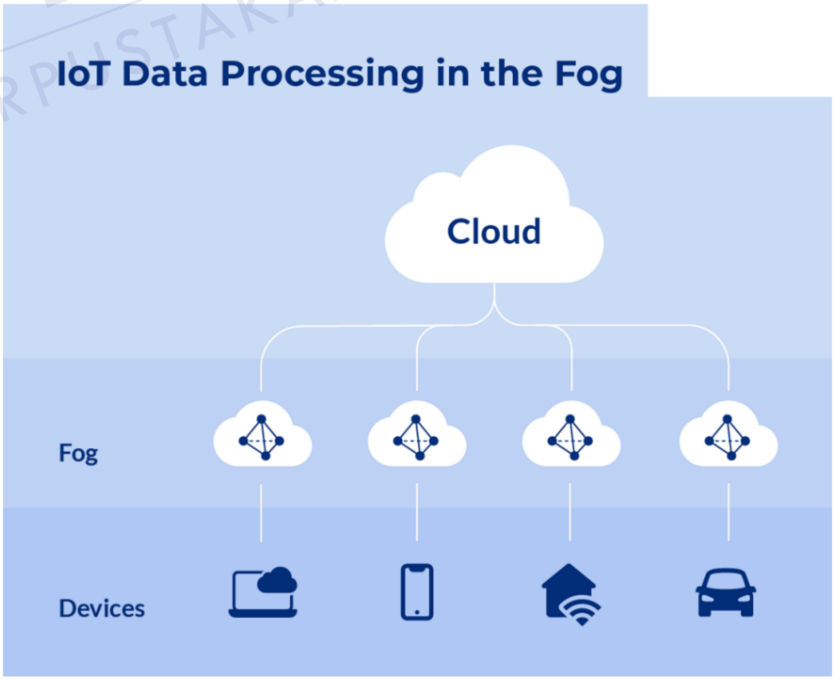

Figure 2.2: Fog Computing Architecture

2.5 Cloud and Fog Comparison

The notions regarding cloud & fog endure extremely similar. On some parameters, however, there a distinction between cloud & fog computing. Table2.1 summarises key characteristics regarding fog & cloud via help you better grasp differences between two[7].

Table 2.1: Comparison table regarding Cloud & Fog Computing[7].

Parameter	Cloud	Fog
Architecture	Centralized	Distributed
Communication with devices	From a distance	Directly from the edge
Data processing	Far from the source of information	Close to the source of information
Computing capabilities	Higher	Lower
Number of nodes	Few	Very large
Analysis	Long term	Short term
Latency	High	Low
Connectivity	Internet	Various protocols and standards
Security	Lower	Higher

2.6 Ultra-Reliable Low Latency Communications

To satisfy the requirements of emerging applications such as intelligent transportation, augmented/virtual reality, industrial automation, etc., Third Generation Partnership Project (3GPP) defined three main service categories in 5G New Radio: Enhanced mobile broadband (eMBB), Massive machine-type communication and URLLC. In these three service categories, the physical design of URLLC is the most challenging one because two conflicting factors of reliability and latency have to be coped with at the same time.

In classic communication, one of two factors must be sacrificed to attain the other factor. To achieve a low latency, a shorter packet has to be used that causes a degradation in channel coding and results in a decrease of reliability. In contrast, to improve the reliability, while a bigger number of retransmissions can be used in eMBB transmission, latency requirement limits the number of retransmissions in URLLC transmission. Moreover, if more time domain resources are consumed due to an increase of parity check bits in the low code rates, it also increases latency and reduces the system efficiency.

Figure 2.3 shows the emergence of unprecedented services and applications such as autonomous vehicle and drone-based delivery, smart home and factory, remote surgery, and artificial intelligence(AI) based personal assistant[8].

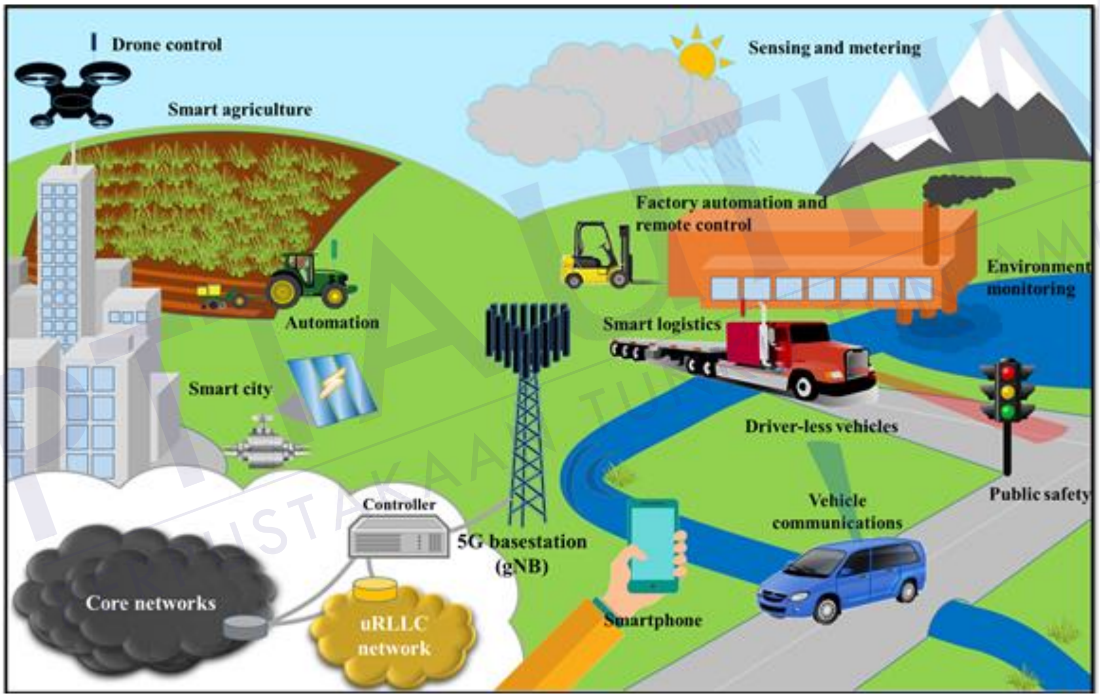

Figure 2.3: Overall 5G systems with Key use cases

2.7 Enhanced Mobile Broadband Communications

Around 95% of mobile data traffic will be expected from smartphones by the end of 2024. The number of mobile subscribers is expected to rise to 8.8 billion. Mobile traffic is forecasted to reach 120 ExaBytes per month. Besides the increase of traffic volume and the number of subscribers, the subscriber habits are also changing with smartphones. Smartphones equipped with modern applications are replacing traditional services like Short Message Services (SMS) and circuit switched voice calls. Communication applications take approximate 30% of the time spent by smartphone subscribers such as traditional voice calls, social networking and instant messaging applications. These kinds of applications need less amount of data transfer but more frequent connections when accessing 5G mobile communication network. Acceptable quality level for communication applications and downlink throughput rate with 90% probability of seventeen cities are shared in Application Coverage in Cities Report.

The number of subscribers, traffic and subscriber habits are continuously evolving and transforming. This renders the resource distribution between subscribers s an important and challenging problem. These changes in user behaviors and application requirements necessitate a balance between fairness and throughput performances and therefore challenge commercially available scheduling algorithms such as Round Robin (RR), best CQI and PF. Consequently, a new scheduling algorithm in 5G mobile communication data transmission system to distribute resources is sorely needed to obtain efficient resource management[9].

2.8 QOS Parameters

Enterprise networks need to provide predictable and measurable services as applications -- such as voice, video and delay-sensitive data -- to traverse a network. Organizations use QoS to meet the traffic requirements of sensitive applications, such as real-time voice and video, and to prevent the degradation of quality caused by packet loss, delay and jitter.

Organizations can measure QoS quantitatively by using several parameters, including the following:

a. Latency: it is also called ‘ping’ that is a critical factor for the future generation networks/applications. It can be reduced by the newer technologies as shown in Figure 2.4 but it cannot be eliminated. If the latency or end-toend delay is too high, an interactive communication is difficult or impossible.

b. Throughput: Bandwidth is the capacity of a network communications link to transmit the maximum amount of data from one point to another in a given amount of time. QoS optimizes the network performance by managing bandwidth and giving high priority applications with stricter performance requirements more resources than others.

c. Bit Error Rate: Packet loss is one of the crucial QoS parameters because it will affect many applications. Packet loss usually occurs when packets are transmitted but a few are not received at the endpoint[10].

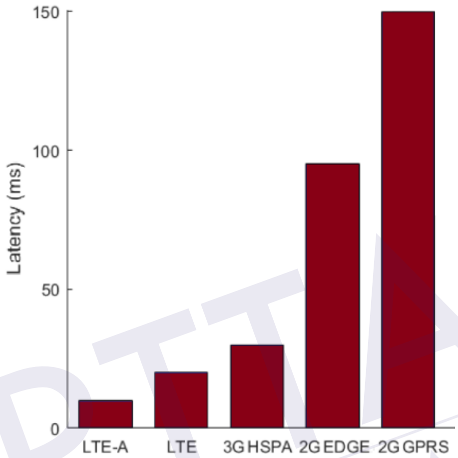

Figure 2.4: Comparison of Latency between Different Technologies

2.9 Resource Allocation Using Game Theory

Game theory is a mathematical tool that analyzes the strategic interactions among multiple decision makers. Three major components in a strategic-form game model are the set of players, the strategies/ action space of each player, and the utility/payoff function, which measures the outcome of the game for each player. In cognitive radio networks, the competition and cooperation among the cognitive network users can be well modeled as a spectrum sharing game. Specifically, in open spectrum sharing, the players are all the secondary users that compete for unlicensed spectrum; in licensed spectrum sharing, where primary users lease their unused bands to secondary users, the players include both the primary and secondary users.

Researchers have proposed various approaches to optimally share the available resources using cognitive radio technology in different scenarios. Since competitors for spectrum rights often belong to different authorities, they have no incentive to cooperate with each other and may act selfishly in order to maximize their own revenues. Therefore, game theory, which analyzes the conflict and cooperation among intelligent, rational decision makers, is an excellent tool and has been widely used in designing efficient spectrum sharing schemes[11].

2.10 AES Security Algorithm

AES is a symmetric algorithm that is one of the most efficient. The benefits It offers excellent protection against intruders. Because Brute Force and Linear Crypt Analysis were not created at the time of its conception, one of its primary drawbacks is that its clouds are vulnerable to attacks such as Brute Force and Linear Crypt Analysis. We have concentrated on AES 128 for data encryption in this work. There are four stages in the AES algorithm[12].

i. Substitute Bytes
ii. Shift Rows
iii. Mixing Columns
iv. Add Round Key

2.10.1 Substitute Bytes

Each byte of incoming data gets replaced by a byte from the substitution table in this phase (S-box) as shown in Figure 2.5. The result is in a matrix of four rows and four columns.

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APPENDIX A