Faculty of Electrical and Electronic Engineering Technology

DESIGN ENERGY EFFICIENT FOG SERVER PLACEMENT ARCHITECTURE FOR SMART CITIES USING MILP MODEL

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEDICATION

This specially dedication goes to both my parents, my beloved mother, Puan Nik Norsilawati Binti Nik Ismail, and my beloved father, Encik Rasidi Bin Nah @ Ab Rashid, thank you for supporting me emotionally and physically throughout this project was done. I also owe a big thanks to my supervisor, Ts. Dr. Ida Syafiza Binti Md Isa and my co-supervisor, Encik Vigneswara Rao A/L Gannapathy for all the knowledge they had shared with me, guide me with patience and all the precious memory we had throughout completing this work. I am so honoured to be under their supervision.

ABSTRACT

Smart city based on Internet of Things (IoT) brings a lot of benefits to the users. Daily tasks can be done easily with the presence of the IoT devices such as smartphones, laptops, and tablets. However, all these IoT devices requires a high processing which leads to energy consumption issues. To overcome this issue, an optimization works is proposed. This optimization work will result in reduction of energy consumption at the fog servers and network equipment. Energy efficiency plays one of important role in determining the performance of IoT systems. This work develops a smart city fog architecture where the size of the considered city is 277 km^2. The tourist spots in Bandaraya Melaka, Malaysia will be considered as the candidate location to place the fog servers. This project is a simulation-based work where all the optimization was done in A Mathematical Programming Language (AMPL) software with CPLEX solver. The optimization using Mixed-Integer Linear Programming (MILP) model is used to determine the optimal number and locations of fog servers in a city to process the data received from Internet of Things (IoT) devices. Furthermore, an evaluation on the total energy consumption considering a different processing capacity and power consumption is conducted. This study reveals that the total energy saving of 58.6%, 77.2%, and 78.9% are achieved by implementing the optimization approach when using Fog Server A, B, and C respectively.

ABSTRAK

Bandar pintar berkonsepkan *Internet of Things (IoT)* membawa banyak kebaikan kepada pengguna. Tugasan harian dapat dilakukan dengan mudah dengan adanya peranti IoT seperti telefon pintar, komputer riba, dan tablet. Namun, penggunaan peranti IoT ini memerlukan pemprosesan tinggi yang membawa kepada masalah penggunaan tenaga. Untuk mengatasi masalah ini, kerja pengoptimuman dijalankan. Kerja pengoptimuman ini akan mengurangkan penggunaan tenaga di *fog server* dan alatan rangkaian. Kecekapakan tenaga memainkan salah satu peranan penitng dalam menentukan prestasi sistem IoT. Projek ini merancang seni bina *fog* untuk bandar pintar yang berkeluasan 277 km^2. Kawasan pelancongan di Bandaraya Melaka, Malaysia akan dipertimbangkan sebagai penempatan calon *fog server*. Projek ini adalah kerja simulasi di mana kerja pengoptimuman dijalankan menggunakan perisian A Mathematical Programming Langguage (AMPL) dengan CPLEX solver. Kaedah pengoptimuman menggunakan model *Mixed-Integer Linear Programming (MILP)* bertujuan untuk menentukan jumlah dan lokasi *fog server* yang optimum di bandar untuk memproses data yang diterima dari peranti *IoT*. Kemudian, penilaian terhadap penggunaan tenaga oleh sistem dengan menggunakan *fog server* dengan kapasiti pemprosesan dan penggunaan kuasa yang berbeza-beza akan dijalankan. Hasil kerja ini menunjukkan bahawa terdapat jumlah penjimatan tenaga sebanyak 58.6%, 77.2%, dan 78.9% dengan melaksanakan pendekatan pengoptimuman apabila menggunakan *Fog Server A*, *B*, dan *C* masing-masing.

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LIST OF SYMBOLS

W	-	Watts
J	-	Joules
Hz	-	Hertz
Bps	-	Bits per seconds
MIPS	-	Million instructions per seconds

LIST OF ABBREVIATIONS

AMPL	-	A Mathematical Programming Language
FN	-	Fog Nodes
FOCAN	-	Fog Computing Architecture Network
GA	-	Genetic Algorithm
IoE	-	Internet of Everything
IoT	-	Internet of Things
MILP	-	Mixed-Integer Linear Programming
PSO	-	Particle Swarm Optimization
QoS	-	Quality of Service
VM	-	Virtual Machines

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CHAPTER 1

INTRODUCTION

1.1 Background

Cisco invented fog computing in 2012 where it focused on the scalability and latency in Internet of Things (IoT) [1]. The aim is to increase the ability of IoT devices where to handle a huge infrastructures and big data volumes for real time low-latency applications for instance, smart home and wearable health monitors. Basically, cloud computing is a computing services that delivery on-demand while fog computing is a decentralized computing infrastructure or process in which computing resources are located between the data source and the cloud or any other data center. Fog and cloud computing are interconnected. To make it simple, fog is a mini version of cloud computing. It has multiple edge nodes that directly connected to physical devices. Fog computing is a type of computing that acts as a bridge between the remote servers and hardware. It controls which data should be transmitted to the server and which should be processed locally. Fog acts as an intelligent gateway that offloads cloud leading to more efficient data storage, processing, and analysis.

Generally, fog computing for IoT applications architecture consists of three layers which are cloud layer, fog layer and device layer [2]. Meanwhile, the cloud layer consists of different servers such as cloud server, application server, data server, data centers and operation centers. The fog layer comprises various communication technologies ranging from Bluetooth to satellite links. The device layer includes mobile devices such as cellphones, watches, vehicles and fixed devices such as desktop computers, routers and switches. Fog computing has lots of advantages over cloud computing. This includes low latency, high power efficiency besides high Quality of Services (QoS).

However, there is always a lack of something in an invention. For example, the complexity of the network, security issues, authentication issues, maintenance issues and power consumption issues. All these issues encourage more research work to be done in future to overcome it. Numerous devices and different fog nodes present in a fog computing architecture contributes to a less secure environment. This will lead to security issue where hackers can easily impose fake Internet Protocol (IP) address in them gaining access to the respective fog nodes. The number of fog nodes present in a network is directly proportional to the energy consumption [3]. Therefore, more energy will be consumed when more fog nodes are deployed in the network to servers in the IoT devices.

Many alternatives have been proposed to solve the power consumption issues faced when deploying the fog network. Therefore, in this work, a solution based on Mixed-Integer Linear Programming (MILP) is proposed to optimize the number and location of fog servers in order to minimize the energy consumption.

1.2 Problem Statement

In this era of technology, Internet of Things (IoT) devices are commonly used and brings a sea change to human's daily life. For instance, smart cities, smart car and smart home. Smart cities can make a better decision throughout the data it collects from about infrastructure needs, transmit demands, and crime and safety.

By using the current smart cities applications, cities are improving quality of life indicator like crime, traffic and pollution. Besides that, energy distribution, streamline trash collection, traffic congestion, and even the air quality can be improved with help from the IoT applications. However, the development of millions of IoT devices results in large amount of data being created at a rapid rate which costs a high energy usage.

Due to inefficient energy use, the need to propose a solution to solve this issue is a must. In order to amend the problems, an optimization method using Mixed-Integer Linear Programming (MILP) model is proposed in this work to overcome the stated issues. The MILP model will determine the optimal number and location of fog servers in a city to process the data receives from any IoT devices. This will result in the reduction of energy consumption of the fog servers and networking equipment. Therefore, in this work, a fog architecture is proposed for smart city where the location and the number of fog servers is optimize using MILP model.

1.3 Project Objective

The main aim of this project is to propose an energy efficient fog computing architecture for smart city. Therefore, the objectives of this work are as follows:

a) To develop a mathematical model using a Mixed-Integer Linear Programming (MILP) model to optimize the number and location of fog servers in the network of smart city application.

b) To evaluate the performance of the proposed fog architecture in terms of energy consumed by the networking equipment and fog server.

c) To evaluate the performance of the proposed fog architecture considering different processing capacity and power consumption of fog server.

1.4 Scope of Project

The scope of this project are as follows:

a) An energy efficient fog computing architecture will be proposed for smart city. The size of the considered city is 277 km^2.

b) A MILP model using A Mathematical Programming Language (AMPL) software will be used to model the network to optimize the number and locations of fog server.

c) The performance of the fog architecture will be evaluated in terms of energy consumption of the networking equipment and fog servers.

1.5 Thesis Outline

This project proposes an energy efficient fog computing architecture for smart city. In this thesis, there are five chapters where each of the chapter explained important points to execute the project. Chapter 1 gives an overview on the introduction to the research background, problem statements, project objectives and scope of project. This chapter provides on the problem being investigated. Next, Chapter 2 will compile all the related past research paper and the comparison of the previous works in terms of methods, advantages and drawback. Then, an established methodology will be proposed. Chapter 3 discusses all the methods used to achieve the aim of this project. Next, Chapter 4 provides the results of the proposed work. Therefore, all the outcome of this project such as analysis, data tabulation, results and discussion will be documented in Chapter 4. Finally, Chapter 5 concludes all the work done in the project. Moreover, the recommendation or any future work is also portrayed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an elaboration on the related previous past work. There are a few studies focused on the development of MILP model with the aim of energy efficiency optimization. The previous past research on the fog architecture and service placement approaches is also elaborated in this chapter.

2.2 Fog Computing Architecture

Paper [4] discussed the several architectures used in the existing works on fog computing. This work results in better acknowledgement on a few aspects of fog computing architecture. A conceptual framework of fog computing architecture is presented in the aspects of system, device and functionality. The information collected in this work contributes a lot to the future studies related to the fog computing architecture.

In work [5], this paper proposed a flexible Fog Computing architecture in which the main features are that it allows us to select among two different communication links (WiFi and LoRa) on the fly and offers a low-power solution. The proposed Fog Computing architecture is formed by sensor nodes and an Internet of Things (IoT) gateway. This approach is capable of solving the previous issues related to the real-time processing and the communications bandwidth, as well as adding new advantages to the existing architectures.

Work [6] presents the multi-tiered fog computing architecture of smart city named FOCAN which consists of IoE tier and FN tier as shown in Figure 2.1. The IoE tier layer is the ellipse shaped supported by the connection between IoT devices. In FN tier, the fog nodes acts as a virtual data centre that deploys the fog service. This network minimizes the latency and energy consumption of IoE devices.

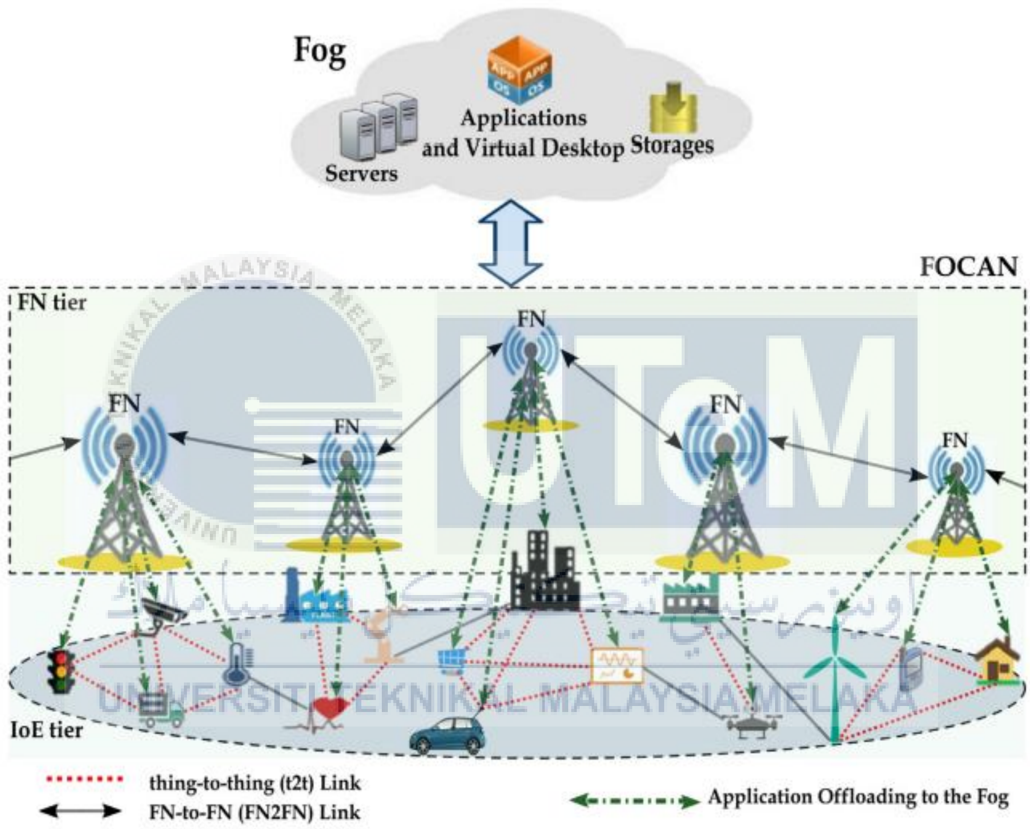

Figure 2.1 Fog-Supported Smart City Architecture Network (FOCAN)

Authors in paper [7] develop a three layered architecture of smart city as in Figure 2.2. The first layer consists of building control unit, smart sector and smart city. In the middle tier, there are fog nodes with VM implementations, and the upper tier is the cloud layer. As a finding, the delay and latency is reduced by implementing the GA algorithm to balance the VMs request at cloud and fog.

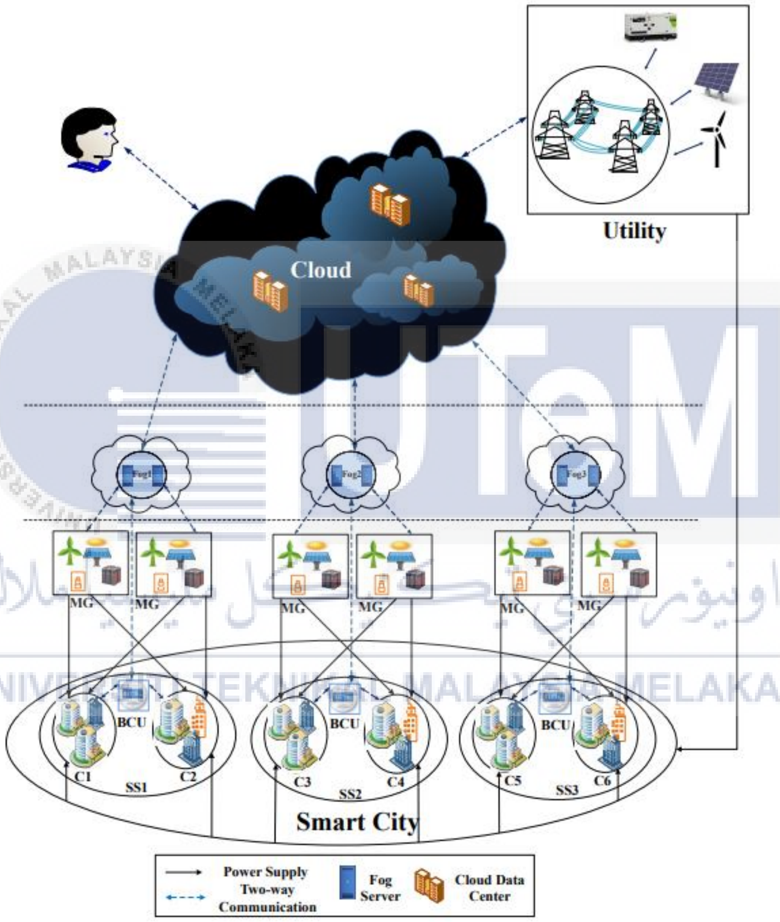

Figure 2.2 Fog-Cloud Smart Environment Architecture