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بسم الله الرحمن الرحيم

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HANAA ALY

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Department of Computer and Systems Engineering

Fog Computing as a Platform for Intelligent Transportation Applications

A thesis submitted in partial fulfillment of the requirements of
Master of Science in Electrical Engineering
(Department of Computer and Systems)

By

Rehab Shahin Amin Abdellatif

Bachelor of Science in Electrical Engineering
(Department of Computer and Systems)
Faculty of Engineering, Ain Shams University, 2012

Supervised By

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Prof. Dr. Salwa Mohamed Nassar

Cairo, 2021

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Date: 12/04/2021

Statement

This thesis is submitted as a partial fulfillment of Master of Science Degree in Electrical Engineering, Faculty of Engineering, Ain shams University. The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Intelligent Transportation Systems (ITS) are very important component of smart cities. One of the most important technologies that are utilized to support ITS is Vehicular Ad-hoc Networks (VANETs). In VANETs, vehicles communicate with each other (V2V) or with the infrastructure (Roadside Units) (V2I). Roadside Units (RSUs) collect data from vehicles in the coverage area and send it to cloud servers through the Internet. Cloud servers have high performance computational and storage capabilities that ITS applications require for data processing. However, due to the real-time requirements of the ITS applications, cloud approach alone cannot be guaranteed to satisfy the strict time constraints due to long latency access of the centralized cloud server. Fog Computing is an emerging approach that extends the services of cloud computing to the edge of the network. Fog Computing can be utilized in VANETs through deployment of fog nodes into RSUs. One of the major challenges to accomplish this deployment is identifying the optimum number, locations and computational capabilities of the RSUs particularly in urban regions where obstacles exist heavily inside the coverage area of the RSUs. The optimization problem of fog-based RSU placement and configuration is considered as the main contribution of this thesis. A new methodology is proposed that takes care of the obstacle density in the area under investigation and its effect on the signal attenuation. Additionally, a new modeling for the problem is introduced. The problem is formulated and solved as a Satisfiability Modulo Theories (SMT) problem. This approach is evaluated on three different scenarios. The approach outperforms other solutions in the literature in terms of cost and the percentage of the messages that are not processed due to lack of processing capacity, which in turn contributes in the enhancement of the ITS.

Thesis Summary

Fog Computing is introduced as a platform for intelligent transportation applications. A new strategy, namely Fog-based RSU Optimum Configuration and Localization (Fog-ROCL), is proposed to deploy fog nodes into the Road Side Units (RSUs) fixed on the roads where vehicles move. The strategy aims at the selection of the optimum locations for the fog-based roadside units to achieve the optimum level of service quality at minimum cost. An optimization method is used which is based on the concept of Satisfiability Modulo Theories (SMT).The contributions of this thesis are listed as follows:

- A new strategy, namely Fog-based RSU Optimum Configuration and Localization (Fog-ROCL), is proposed. The proposed strategy addresses the challenges of the optimum distribution of fog-based RSUs in a target urban area using a cost efficient approach. The objective is to satisfy a set of quality measures including coverage and processing demand with minimum cost. The proposed strategy has three main parts, a pre-processing module, an optimization module and an evaluation module.
- The pre-processing module extracts a set of potential locations of the fog-based RSUs based on the road coverage percentage across the given area. The algorithm considers the attenuation of signal propagation due to obstacles, which exist heavily in urban regions. In the optimization module, a new formulation for the RSU placement optimization problem is proposed. The problem formulation is based on the concept of Satisfiability Modulo Theories (SMT), which is a type of constraint satisfaction problems. The proposed model has three different versions which formulate the problem from three different perspectives. Moreover, the proposed model features the heterogeneity of RSUs in terms of computational capabilities to add flexibility and reality to the fog system.

- The proposed model is able to select the number and locations of the RSUs, among the set of the RSU potential locations, and the type of each RSU based on the computational demand generated within its coverage region. Hence, cost is minimized.

The proposed strategy is evaluated using a VANET simulator. Three main scenarios are tested and the results are compared against each other and against multiple reference strategies from the literature.

The thesis is organized as follows:

- Chapter 1: gives an introduction about the problem to be solved.
- Chapter 2: discusses the background of the topics upon which the proposed work is based. Additionally, a literature review of the previous work is discussed.
- Chapter 3: discusses SMT, SMT solvers and how it is used as an optimization method.
- Chapter 4: introduces and discusses the proposed Fog-ROCL strategy and the proposed model which is based on SMT.
- Chapter 5: discusses the evaluation of the proposed strategy using three different evaluation scenarios.
- Chapter 6: discusses the conclusion of the thesis and potential directions for future work.

Key words: Fog Computing, Fog Node, Intelligent Transportation Systems (ITS), Optimization, Roadside Unit (RSU), Satisfiability Modulo Theories (SMT), Vehicular Ad-hoc Networks (VANETs).