Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 203 (2022) 413–419

Procedia Computer Science

www.elsevier.com/locate/procedia

The 9th International Symposium on Emerging Inter-networks, Communications and Mobility (EICM)
August 9-11, 2022, Niagara Falls, Ontario, Canada

Collaborative Edge Mobile Model for IoT Emergency Management

Hamid Mcheick [a,*1] , Fawzi Al Mestrah [b], Fatima Shbib [b], Zeinab Koteiche [b]

[a]*Department of Computer Science and Mathematics University of Quebec at Chicoutimi, Chicoutimi, G7H 2B1, Canada*
[b]*Department. of Computer Science and Mathematics Lebanese University, Beirut, Hadath, Lebanon*

Abstract

Traffic congestion has resulted in the loss of human lives globally as a result of failing to transfer accident victims, critical patients, medical equipment, and medications on time. With the ever-increasing volume of vehicular traffic, the convergence of Edge-based approaches has emerged as a potential platform for a Collaborative Edge Traffic Management Model. The collaborative edge model focuses on three objectives reducing the latency of the ambulance arrival to the accident, delivering the ambulance to the closest hospital and taking into consideration the patient case severity by a set of collaborating edges communicating to facilitate and manage this process.

Keywords: Edge Computing, Collaborative Edge, Real Time Response, Traffic Management, Internet of Things for Emergency system.

1. Introduction

1.1. *Motivation*

Because of the world's rapid population increase, there is a high need for smart city initiatives. As a result, an intelligent Traffic Control system (TCS) is necessary to handle emergency vehicle traffic with least delay. The sight of slow moving, or stuck ambulances in traffic is very common in most of these cities. Road traffic has not only wasted time, caused property damage, and polluted the environment, but it has also resulted in the deaths of accident victims.

* Corresponding author: Tel.: +1-418-545-5011 EXT 5676; fax: +14185455017.
E-mail address: hamid_mcheick@uqac.ca

1877-0509 © 2022 The Authors. Published by Elsevier B.V.

10.1016/j.procs.2022.07.054

Sometimes medical equipment, essential patients, and required medications are not delivered on time. Reducing the response time by just one minute increases the survival rate of the patients with sudden cardiac arrest by 24% [1].

1.2. Problem

Currently, none of the available traffic management systems can immediately remove traffic congestion in the event of an emergency, enabling vehicles such as ambulances, fire engines, and police cars to pass. With the number of cars on the road increasing at an exponential rate, there is a critical need for Intelligent Traffic and Transport Systems for ambulances that not only prioritize the passage of emergency vehicles with minimal delay, but also take existing infrastructure into consideration. Traditionally the traffic management system is run in the cloud, where the server is hosted. The round-trip delay to a central cloud server and back adds to latency, and the back-haul traffic over internet links lack service level agreements (SLAs) for predictable performance. SLA today is considered a standard service agreement between various parties to define initial constraints between partners. The SLA has been used in various fields such as telecommunications, call centres, security, cloud computing, and health systems. High-throughput 5G networks are enabling edge processing, allowing the coordination of traffic light to minimize back-haul traffic. The use of a traffic light to control traffic is an essential component of any effective traffic management system. At the moment, most countries pick the green light sequence without considering emergency vehicles such as ambulances, police cars, fire engines, and so on, forcing emergency vehicles to wait and causing loss of lives and assets [1]. Additionally, vehicular population increases the "response time" of emergency vehicles which is defined as nothing but the period between the time whenever a call is received by an emergency service provider and the arrival time of an ambulance to an emergency site [1].

Edge Computing is one of the solutions proposed to reduce the response time. The emergence of IoT-Edge computing made a shift to this process by bringing computational processes closer to the origin of data (edges) [2]. Since the computations are done in the edges, the systems do not suffer latency, and real-time processing would work better for a traffic management. It provides faster response and quick analysis in emergency scenarios. The rise in Edge computing was also prompted by the growth of IoT devices, which communicate a large amount of data to and from cloud services during its operations [3].

1.3. Objective

Taking the previous mentioned issues under consideration, we introduce a collaborative edge-based system that manages the passage of the ambulance from the moment of receiving the emergency call until delivering the patient to the hospital, with the service of treating the patient on the way with the suitable band aid according to his case. In addition, we focus on reducing the cost by using the ambulance devices like mobile with low cost.

1.4. Contributions

This research paper proposes a collaborative edge system that control traffic light system based on the road selected for the ambulance to reach the accident location as fast as it can. We proposed architecture for this system focusing on facilitating the process of communication between the ambulance and the traffic light edges to reduce the latency in critical situations.

1.5. Organization of the paper

This paper is organized into four sections. In the section 1, we make a brief outline of the research and describe the motivation, problem, objectives, and our contributions. Section 2 surveys the standard traffic light systems. Section 3 describes the workflow and collaborative edge mobile architecture. A workflow with scenario and discussion are given to illustrate this architecture. Finally, we have presented the research conclusion and future works.

2. Existing Standard Traffic Light Systems

The standard traffic lights work by signalling devices installed on the road at intersections that are used to control traffic movements. A traffic light is typically made up of three lights. They are red, yellow, and green color. When the red light is illuminated, it signals to motorists facing the light to stop, while the yellow light indicates caution to prepare for a halt short of the intersection. The green light indicates that you should go in the direction indicated. The sequence of traffic lights may differ from one another, and there may be unique restrictions or a set of lights for traffic turning in a specific direction [4]. This is the main function of the traffic light system; it regulates the traffic but without taking emergency cases into consideration. Our focus is on proposing a system of multiple edges collaborating together to facilitate the passage of ambulances.

3. Collaborative Edge Mobile Model

3.1. *Workflow*

Figure 1 depicts a scenario of the traffic light system in case of emergency. When a hospital receives an emergency call for an accident or a patient case, it has to issue an ambulance to the location of the patient or the accident. First, the ambulance should communicate with the nearest edge and send its start location and target location. The case here is severe, so reducing the latency time is our biggest challenge. The edge has to provide for the ambulance the nearest path with the least traffic, for finding the nearest path it will be using Google maps service, but the main goal here is to manage the passage of the ambulance by controlling and reducing the traffic on the chosen path. We are working in the context of a smart city, so there will be sensors devices distributed on all the traffic lights regulators. Moreover, for working in a real-time manner small smart device will be installed in the ambulance, it will continuously send location updates to the edge. When the ambulance become close to a traffic light regulator, the edge server checks the traffic in the zone using Google map API for traffic tacking. Google Maps analyses historical traffic patterns for routes over time to estimate what traffic will look like in the near future. The software then combines this database of historical traffic patterns with live traffic conditions, using machine learning to generate predictions based on both sets of data [5]. When we use Google Maps to navigate it shows whether the traffic along the route is massive or light, an estimated travel time, and the estimated time of arrival. According to the traffic load, if it is heavy, the edge notifies the next edge before at least 1 km or 500 m in case of light traffic. The edge here has to generate a signal to the regulator that will turn the lights to green to facilitate the passage of the car and reduce the traffic. This action will be applied to all the regulators on the ambulance path to facilitate its passage and control the traffic.

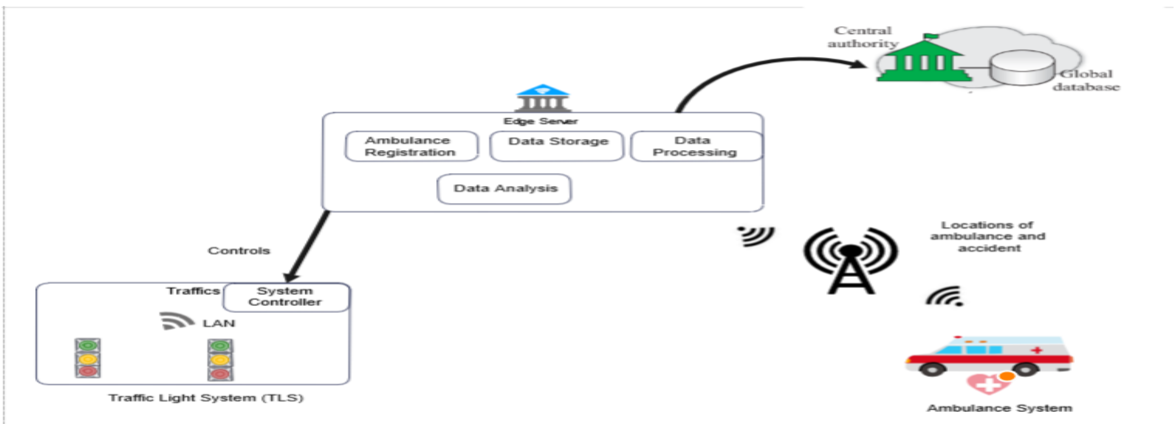

Fig. 1. Collaborative Edge Mobile Architecture Model.

3.2. Traffic Management System Architecture

3.2.1. Traffic light system (TLS)

In Figure 2, we proposed architecture for the traffic light system. After receiving data from the ambulance about the accident and after the edge selects the shortest path to go throw it, traffic lights status should be updated based on the route specified by the edge.
Traffic light in each zone should be synchronized and dependent from each other. Each zone or each group of traffic lights should have a system controller to manage the status of traffic lights in such a zone.
For solving this problem, we proposed architecture that contains those components:

- Edge consumer API: after being selected the shortest road by the edge, the edge detects the traffic lights in this road and manage the status of the traffic lights to minimize the traffic.
- Device controller: is responsible to send data received by the edge consumer API to the operating system layer to be managed.
- Operating system layer: after receiving data, OS layer manage each status for each traffic light and send this data with configuration to the hardware layer.
- Hardware layer: receive data and status configuration for each traffic light, open a connection with every traffic light via Bluetooth or LAN and send the new status configuration to the connected traffic light to be updated.

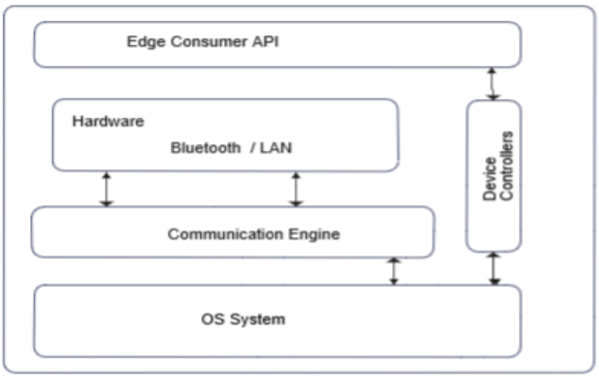

Fig. 2. Traffic Light System (TLS) Architecture.

3.2.2. Edge Server

In the edge server we have three main services:

- Ambulance Registration: When joining the edge, a unique id is given to the ambulance, which is used for identifying its data. A unique id to track the ambulance since there are many heterogenous vehicles moving in the area
- Data Storage: As a data repository in a region, the edge stores incoming data from the ambulance in local storage. The edge will store all information related to the ambulance and the patient. Besides, history information about data transmission, data processing, data access and data storage is recorded orderly.
- Data Analysis and Processing: For low-latency response in emergency situations, data analysis and processing take place in the edge computing environment. Some of the available services are analysing the traffic in its zone, which results in the instructions needed to control the traffic light and to guide the

ambulance on its path, or analysing the patient case to return the suitable band-aid measures to the ambulance.

3.2.3. Ambulance System

We integrated here a small mobile device that will be connected to the internet and have IP address. This article introduces the best way for establishing a connection between mobile device and edge, and show the configuration needed for an edge to ensure the best real-time communication with low latency [6]. This device will be communicating with the edge in a real-time manner. As for the first communication the ambulance will communicate with the nearest edge and send the accident or patient location. In addition, the ambulance will send information about the patient's case so the edge will process the data and send the appropriate primary measures that can be taken to treat the patient on the way for example if he needs oxygen the edge may process and analyse the amount of oxygen needed. The ambulance will be continuously communicating with the edges for location updates on the route. The edge will guide it to arrive to the nearest hospital.

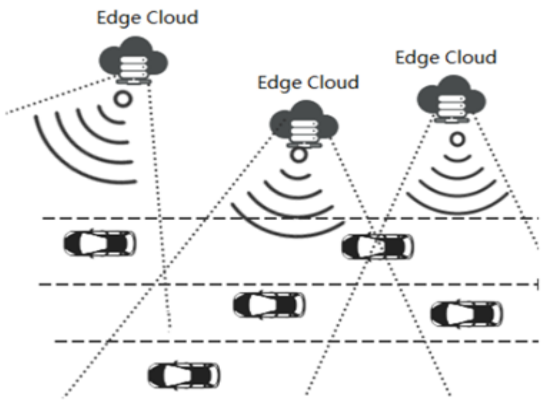

Fig. 3. Collaborative Edges and Ambulance Communication.

3.2.4. Collaborative Edge

Collaborative Edge, which connects the edges that are geographically distributed despite their physical location [6]. The geography of a country is divided into many zones. In collaborative edge computing, the tip and edge nodes must work together to process the tasks. In each zone we have an edge that is responsible for handling and managing the traffic in its zone. On its way from the start location until arriving to the hospital, the ambulance passes by several zones. When moving from one zone to another, as illustrated in Figure 3, [7] there will be collaboration between these two edges. Before going out the current zone and boundaries where the ambulance is found in, the current edge has to communicate with the next near the edge. It will send to the next edge based on the history of the ambulance and the patient and notify it that the ambulance will be in its zone soon to take the appropriate measures and manage the traffic in its zone to continue the task.

Another kind of collaboration between edges is for finding the appropriate nearest hospital that has available places for the patient, since in some cases patient vacant places might not be available. In the zone where the accident happened, the edge has to find nearest hospital. Therefore, it will communicate with all other edges. A request will be broadcasted to all edges attached with the patient data and case severity. The edges receiving the request will select the appropriate hospital found in its zone and will return a response.

Moreover, the edges will subscribe to the events and accidents that might occur on its neighbouring edges. Therefore, if an accident occurs in an edge zone, the edge will publish a message to all the neighbouring subscribers, on receiving, a notification the edges near the accident will take corresponding measures to ease and manage the traffic in their zone if needed in case the ambulance will pass by its edge.

- The advantages about the proposal for traffic management systems are summarized as follows: Real-time system response: ambulance and patient data is transmitted to edge servers for prompt processing with lower response time.
- Balancing workload allocation: Geo-distributed edges cooperate with each other to process location and patient data synchronously when necessary. With workload balancing, scalable network management is supported to cope with the exponential data growth [8].
- Reduced Latency: Unlike cloud computing, which relies on a single data centre, edge computing works with a more distributed network, eliminating the round-trip journey to the cloud and offering real-time responsiveness. It keeps the heaviest traffic and processing closest to the end-user application and devices that generate and consume data. This dramatically reduces latency and leads to real-time, automated decision-making [9]. The ambulance will be talking with the nearest edge on its way, when it becomes closer to another edge, the task will be forwarded by this edge, this will in reducing the latency.

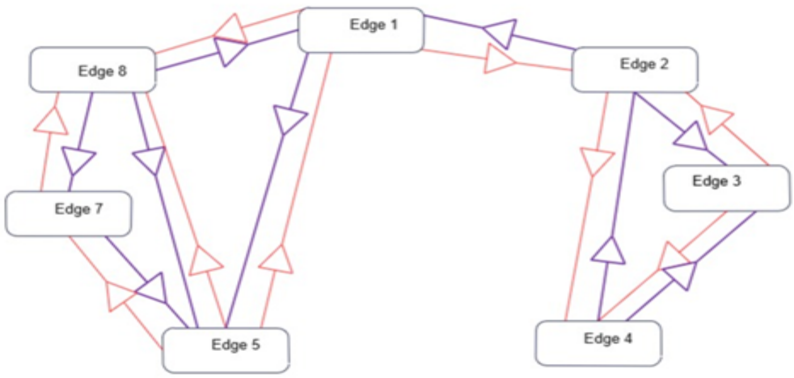

Fig. 4. Publish-Subscribe Pattern Between Edge.

3.3. Discussion

Based on the workflow discussed above and our collaborative edge mobile architecture, we are going to discuss the scenario described above. Our proposed architecture can be used in many critical health situations such as COPD, Asthma, Covid 19. The ambulance mobile device is installed for the communication with the edge servers, this device issue signals to the nearest edge server in a real-time manner so that the edge servers keep track of the ambulance location and the patient situation. The edge servers are responsible for facilitating the passage of the ambulance to the nearest hospital by controlling the traffic in its zone and it also analyses the patient case and return to the ambulance the precautions that could be taken to treat the patient on the way. The edge receives signals from the ambulance, and coordinates the traffic lights on the road by sending directions to the traffic light system. The traffic light system is responsible for changing the traffic light color which is located on the road of the ambulance is passing on. The whole process is done in a collaborative manner between the edges collaborating to reduce the latency as much as possible and also to balance the load on the available edge servers. This whole process facilitates the passage of the ambulance and help on controlling the traffic on the way to reduce the risk on the patient life, which is a critical issue in emergency cases.

4. Conclusion

Several researches have been carried out on intelligent traffic monitoring system, but an efficient solution for emergency vehicles like the ambulance with support of first aid for a patient on the route is yet to discuss. In this work we presented a collaborative edge traffic management system to control the traffic and facilitate the passage of the ambulance on the proximity route from its initial location to the accident or patient site until delivering him back to the nearest hospital taking his symptoms and case in consideration. We mainly focus on proximity of the target (like hospital) and traffic management to reduce the latency time. The system works on the real-time manner within a network of collaborating edges working to gather to assess the ambulance on his way. The main goal is to construct an overall system that is able to provide the complete support for the ambulance to ensure the safety of the patient and reducing the risk on his life. For future directions, we will focus more on finding the convenient primary medical response for the patient that will be analysed and processed in the edge. In addition, we will implement and validate this collaborative system in a smart city.

Acknowledgements

This research was supported and founded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and by University of Quebec at Chicoutimi, Chicoutimi (Quebec), Canada.

References

[1] Nellore, K. and Hancke, G.P., "Traffic management for emergency vehicle priority based on visual sensing", *Sensors*, Vol. 16, No. 11, (2016), 1892.
[2] D. Puthal, M. S. Obaidat, P. Nanda, M. Prasad, S. P. Mohanty, and A. Y. Zomaya. “Secure and sustainable load balancing of edge data centers in fog computing”, *IEEE Communications Magazine*, Vol. 56, No. 5, pp. 60-65, May 2018.
[3] M. Satyanarayanan, “The emergence of edge computing”, *Computer*, Vol. 50, No. 1, pp. 30-39, January 2017.
[4] Nang Hom Kham, Chaw Myat New, “Implementation of Modern Traffic Light Control System”, *International Journal of Scientific and Research Publications*, VOL 4, Issue 6, June 2014.
[5] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, “*Fog computing and its role in the internet of things*,” in Proceedings of the first edition of the MCC workshop on Mobile cloud computing. ACM, 2012, pp. 13–16.
[6] Gopika Premsankar, Mario Di Francesco, and Tarik Taleb,” Edge Computing for the Internet of Things: A Case Study, *IEEE INTERNET OF THINGS JOURNAL*, VOL. 5, No. 2, APRIL 2018.
[7] Weisong Shi, Jie Cao, Quan Zhang, Youhuizi Li and Lanyu Xu,” Edge Computing: Vision and Challenges”, *IEEE*, 2016.
[8] Rong Yu, “EdgeCare: Leveraging Edge Computing for Collaborative Data Management in Mobile Healthcare Systems”, IEEE Access, pp (99) 1-1, March 1, 2019.
[9] Miller, Rich “IoT and Latency Issues Will Guide Edge Deployments. ” *Data Center Frontier*, June 21, 2018.