Towards Time-Efficient Emergency Response in Smart Cities

Final Year Project Interim Report

Nicolas Smith

An interim report submitted in part fulfilment of the degree of BSc (Hons.) in the School of Computer Science and Informatics with the supervision of Prof. John Murphy and moderated by Dr. Soufiene Djahel.

School of Computer Science and Informatics

University College Dublin

04 December 2014

Project Specification

Subject: Road Traffic Simulation, Vehicular Communication Technology
Project Type: Design and Implementation
Software Requirements: Python, C++

General Information: The rapid increase in number of vehicles on the roads as well as the growing size of cities have led to a plethora of challenges for road traffic management authorities, such as traffic congestion, accidents and air pollution. Road traffic congestion is a serious problem that most of big cities in the world suffer from. We distinguish two types of congestion, recurrent and non-recurrent. Recurrent congestion occurs usually when a large number of vehicles use the limited space of road network simultaneously (e.g. weekday morning and afternoon peak hours). Non-recurrent congestion results usually from random events like traffic incidents (e.g. crashed or stalled vehicles), work zones, bad weather conditions and some special events. One of the most critical consequences of traffic congestion is the delay of emergency services, such as police intervention, fire and rescue operations as well as medical services. In such services, a delay of a few minutes may cause human lives risks as well as financial losses.
The aim of this project is to design a solution that reduces the latency of emergency services delivery by dynamically adjusting traffic lights cycles, changing related driving policies, recommending behaviour change to drivers, and applying essential security controls. This will create “**green route”** for these vehicles and significantly reduce their response time, which may save human lives and reduce the induced damage/loss in case of fire or robbery. In this solution, the Traffic Management System (TMS) should be also able to control the behaviour of non-emergency vehicles to ensure minimum number (ideally zero) of crashes, minimum disruption to the regular traffic flow, and satisfaction of security requirements to prevent any misuse of the system.
Mandatory:
1-Familiarize with SUMO and TraCI
2-State of the art on urban traffic simulation, V2V and V2I communication technologies
3-Design a mechanism that allows the traffic light controller to detect the emergency vehicle and apply adequate adaptations, according to the observed traffic congestion state, to speed up its arrival to the emergency location.
4-Implement and evaluate the performance of the proposed mechanism
Discretionary:
1-Evaluate the impact of the proposed mechanism on non-emergency vehicles travel time
2-Evaluate the impact of the proposed mechanism on the achieved traffic load balance
Exceptional:
1-Propose a security scheme to ensure the authentication and integrity of the exchanged messages among the vehicles, as well as among the vehicles and the traffic light controller.

Abstract

The purpose of this project is to design and calibrate the fastest possible emergency response system to be used in a Smart City while ensuring that acceptable congestion levels are maintained. A microscopic road network traffic simulator SUMO (**S**imulation of **U**rban **Mo**bility) in conjunction with a client application TraCI (**Tra**ffic **C**ontrol **I**nterface) which can issue commands and alter the state of a simulation in SUMO are being used for this. The solution will involve using the degree of the emergency along with the level of congestion to decide on the most appropriate adaptation strategy to ensure the fastest response time and the least disruption to regular traffic. The Adaptation Strategy will involve changes to driving policies (such as turning rules, the use of reserved lanes, and the speed limit) and objects in the simulation (e.g. dynamically altering traffic light cycles).

This report will first highlight the main motivation behind this project in part 1, then move on to give an overview of the background research that might be useful in solving the studied problem, and discussing related works. Lastly the preliminary idea of the proposed solution will be presented along with a report of the progress made thus far and the action plan to follow to achieve project objectives.

Table of Contents

1 Introduction

The advent and emergence of Smart Cities grants us an opportunity to prevent and combat a multitude of contemporary problems through more innovative use of ICT (Information and Communications Technology), and intellectual, physical and infrastructural capital. One such problem which motivates this project is inefficiency or latency in emergency response times and the incurred cost in terms of human life and financial loss that could be mitigated with an innovative ICT-driven approach. In Ireland alone 700 fatalities are caused by late response by ambulances as stated in [1]. Smart Cities are by inherently the ideal platform for implementing such an approach.

In the case of fire emergencies, response time requirements in the U.S state that the first fire engine is expected to arrive at the scene of a fire within four minutes of a call or within eight minutes for the full contingent dispatched units (both with a 1 minute leniency window) in 90% of cases [2]. Needless to say, meeting this standard, while clearly necessary, increases the already enormous cost of maintaining a functional fire response service, especially in populated areas which experience heavy congestion. The Fire Department of New York (FDNY) alone reported an expense budget of $1.671 billion in 2012 and is increasing yearly (the same budget was $1.473 billion in 2008 and $1.616 billion in 2010) with approximately 1.43 million Emergency Medical Services (EMS) vehicles and 900,000 fire vehicles dispatched in the same year (461,630 of those responding to life-threatening medical emergencies) [3]. This does not take into account the property damage and loss of life caused by fires which in itself is staggeringly high. In the U.S.A in 2013 there were more than 1.2 million fires, with a fire department responding to a fire every 25 seconds. In the same year 3,240 civilian deaths and 15,925 civilian injuries, not to mention causing $11.5 billion in property damage [4]. The speed required for emergency response also leads to a lot of accidents and injuries, a 1998 study by the National Fire Protection Associations reveal that there were 14,650 accidents caused either en route or on return from a call by fire response vehicles including 1,050 injuries amongst fire response staff or volunteers [5]. The data rather clearly emphasises the benefit of adopting more innovative approaches to Emergency Response services being implemented in Smart Cities to reduce the accidents, deaths and cost resulting from an inferior service.

The investment in Smart Cities at the moment is enormous, with both governments and large companies such as Siemens [6] and IBM [7] funding and researching initiatives to develop Smart Cities. There are several definitions of what exactly constitutes a Smart City, a cooperatively written report led by the Centre of Regional Science in Vienna describes a Smart City as: "*a city well performing in a forward-looking way in these six characteristics* (Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment, Smart Living)" [8]. Several cities are already widely considered to be Smart Cities (notable examples include Vienna, Amsterdam and Tianjin) and the number of Smart Cities is expected to quadruple from 2013 to 2025 with a staggering 88 Smart cities predicted at minimum by IHS (Information Handling Services) with 32 planned Smart Cities in the Asia-Pacific region, 31 in Europe and 25 in the Americas, compared to 21 worldwide in 2013 [9].

It is very clear from the above information that there is both a pressing need for a more optimised ICT-driven emergency response system and a significant opportunity for its implementation with the upsurge of investment and interest in Smart Cities. This project aims to design such a system with the aid of the microscopic SUMO simulator and TraCI to model real-time events and adaptive emergency responses based on the available real-time information. The ultimate goal of the project is to implement dynamic crash detection and emergency dispatch whereby a variety of environmental traffic variables such as road occupancy and traffic speed along with the emergency vehicle's route are combined with the severity of the emergency for the system to decide on an adaptive strategy using V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) technology to notify both infrastructure elements and vehicles on the emergency route and changing driving policies or even re-routing traffic as mandated by the adapted strategy.

2 Background Research

2.1 State of the Art

Traffic Management Systems (TMSs) are currently widely deployed and used across the world, while they may adopt advanced congestion control mechanism, metropolitan areas around the world still suffer from large economic loss and hindrance to emergency services due to congestion. A typical TMS system has four phases of operation as detailed in a paper by Soufiene Djahel *et al* [10]. The first phase is Data Sensing and Gathering (DSG), in which road monitoring equipment measures certain traffic parameters such as speed and occupancy and periodically reports information to a control centre, the monitoring equipment is capable of detecting incidents that require response (i.e. crashes) and reporting them immediately. The second phase, Data Fusion Processing and Aggregation (DFPA) involves analysis of the retrieved data in attempt to extract useful information to be passed on to the third phase, Data Exploitation (DE), in which useful data is used to derive useful statistics such as optimal routes for vehicles and short term traffic forecasts. The final phase is Service Delivery (SD) where useful information is sent to the end-user by a variety of possible mediums including devices installed in vehicles or even via a smart-phone applications.

To look at a tangible incarnation of a TMS, one of the most widely deployed TMS is Split Cycle Offset Optimisation Technique (SCOOT) [11] which is described by its creators as "*an adaptive system that responds automatically to fluctuations in traffic flow through the use of on-street detectors embedded in the road*." SCOOT has proved generally successful with an average traffic delay reduction of 20%, it also offers incident detection, on-line saturation occupancy measurement and emissions estimates. Inductive loops are the primary tool used for the DSG phase, installing and maintaining these is one of the highest costs incurred by using SCOOT. Much like in simulators like SUMO, SCOOT networks represent points of interest such as junctions and crossings with nodes, it divides the area covered by the system into linked regions rather than processing the entire area simultaneously, presumably because of computational cost. SCOOT is used most in the UK, but is also prevalent in South Africa, South-East Asia, North America and several other scattered locations worldwide [12]. The latest version of SCOOT, SCOOT MM SP1, was released in 2010. While it is one of the most prevalent TMS installations it is not by any means the sole option, many alternatives exist such as the open-source Intelligent Roadway Information System (IRIS) developed by the Minnesota Department of Transportation [13] or the Georgia Navigator commissioned by the Georgia Department of Transport and installed in 1996 [14]

V2V (Vehicle to Vehicle) and V2I (Vehicle to Infrastructure) technology are another potential asset for TMS which unfortunately have not yet been exploited even near to their full potential. V2V and V2I allow for the exchange of packets between different vehicles and between vehicles and certain infrastructure elements such as traffic lights, this has a vast scope of potential applications in the field of traffic and emergency response management. For example it allows every enabled vehicle to sense its own surroundings and get information about other vehicles in the vicinity, coupled with GPS enabled devices current and future positions can be combined to create a situational awareness of sorts to facilitate crash avoidance. Similarly a TMS object (such as a Local Traffic Controller) can direct the notification or even re-routing of vehicles which are predicted to experience congestion on their planned route or if lane clearance is required through V2I communication. Alert messages received by vehicles through V2I can also be forwarded to other vehicles that may be out of range through V2V after reception. V2V and V2I comprise the current V2X (Vehicle to Everything) market which is still in infancy but will collect other technologies such as V2P (Vehicle to pedestrian) [27] and V2H (Vehicle to Home) [28]. However the majority of the current V2V market is cornered by aftermarket vendors and V2I is primarily only being used for electronic tolling and repayment. This market trend is expected to experience rapid turnaround soon. The NHTSA (National Highway Traffic Safety Association) published a 304 page report entitled *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application* in August 2014 [15], which assessed very thoroughly the possibility of installing V2V technology into all new light vehicles, in particular looking at the technological scope, safety and legal implications. Several months later the DOT (Department of Transport) announced that it would be deploying V2V technology for light vehicles across the U.S [16]. The V2V technology being installed is set to rely on Dedicated Short Range Communication (DSRC) across a band of 5.9GHz (IEEE 802.11p, specifically reserved for vehicular communications). The NHTSA predicts that roughly 83% (close to 4.5 million) of all light vehicle crashes and 72% of heavy truck crashes in the U.S can be addressed by a combination of V2I and V2V technology [17]. A Dutch company called NXP Semiconductors announced the mass production of V2X chipsets in September 2014, making them the first company to announce mass production of V2X technology components, they will be supplied to Delphi Automotive PLC (one of the biggest automotive parts manufacturers in the world) and will also operate over IEEE 802.11p. The V2X chips are expected to be deployed in vehicles within two years [18].

While the aim of this project involves the alteration of certain elements of a TMS structure, and V2X communications are sure to be vital to the final solution, the primary tool to test and study any proposed solution is a traffic simulator. A vast array of such simulators exist, most of them capable of providing realistic simulations and dynamic runtime applications. The simulator chosen for this project is the microscopic, open-source simulator SUMO, developed by the DLR (German Aerospace Centre) in 2001 [19]. It has evolved since its original incarnation, adding a broad arsenal of additional features to aid simulation tasks. SUMO has both a command line and a GUI version, the GUI version of course being favourable as traffic simulations can be accurately visualised. SUMO is described as a “microscopic” simulator, this merely means that every object, including all vehicles, traffic lights and lanes, is defined explicitly in the simulation. Each vehicle will have its own unique type, size, route and destination as well as local variables controlling everything from departure time and acceleration to CO2 emissions. SUMO runs simulations from configuration files (.sumocfg) which specify a network file defining the road network and a routes file which specifies the vehicles and their routes, as well as any additional input files that may be applied to a simulation (for example a file specifying additional settings). The Network files themselves are also a configuration of several separate files: a node file which defines all the junctions in the grid, an edge file which defines all the possible connections between nodes (i.e. roads) and a connection file which states which edges are connected, i.e. if a vehicle can travel from one edge to another. Simulations are time-discrete, where one simulation step is equal to one second by default. SUMO provides relatively easy means of creating a network, offering an automatic network generation tool ‘netgenerate’ where uniform, ‘spider-shaped’ or random grids of varying sizes and attributes can be created. A ‘netoconvert’ command also exists which allows SUMO to open network files from different source formats including OSM (Open Street Map) Maps and formats belonging to other simulators such as VISSIM. SUMO also supplies users with range of demand modelling features for traffic. Built in elements such as ‘jtrouter’ and ‘dfrouter’ generate random vehicles and trips on a network file, a python script ‘randtrips.py’ is also included which can generate a randomised route file for a simulation given a network file. It is also possible to simulate the use of V2X technologies and even to combine SUMO with network simulation tools like ns3.

	SUMO	**VANETMobism**	**STRAW**	**PTV Vissim**	**SIDRA Trip**
Transport Modes	Multi-Modal	Truck & Cars	Cars	Multi-Modal	Cars
Accuracy	Time Step=1s	Time Step= 1ms		Time Step=0.1s	Time Step= 1s
Scalability	High: Up to 100,000 vehicles	Medium	Medium	Very High : No limit	One car
GUI	2D	Limited	Limited	2D & 3D	2D
Realistic simulation of pedestrians and passenger behaviours	No	No	No	Yes	No
Parking Management	No	No	No	Yes	No
C2X Support	No	No	No	Yes	No
Accurate analysis of single cars trip	No	No	No	No	Yes
Popularity	Very High	Medium	Low	Medium	Low
License needed	No	No	No	Yes	Yes

Figure 2.1 Comparison of Traffic Simulators [10]

As mentioned before SUMO is one of many simulators that could have been used, there is a lot of literature comparing various traffic simulators but SUMO is the common simulator of choice for academic research. Figure 2.1 shows SUMO compared to its main competitors VANETMobism, STRAW, PTV Vissim and SIDRA TRIP based on ten features. From the table it may seem that PTV Vissim is more desirable in terms of features however the fact that it requires a prohibitively expensive license makes it less popular than SUMO.

In 2006 SUMO was extended to work with TraCI, an external application capable of remotely altering SUMO through TCP Socket communications [20]. TraCI allows us to manipulate SUMO simulations dynamically. TraCI is capable of both issuing commands to objects (for example changing the destination or speed of a vehicle or the phase of a traffic light) or simply to retrieve information like the route being followed by a certain vehicle or the exact position of a junction, TraCI can also take charge of initiating simulation steps. TraCI allows us to detect crashes (or initiate them) on the fly then send out an emergency vehicle to the crash location which is essential to test the solution, it also gives us the opportunity to change driving polices (such as speed limits, traffic light phases etc.) temporarily when an emergency vehicle is dispatched. This capability further increases the appeal of using SUMO as a simulator for this project (though it is not the only simulator capable of working with TraCI). TraCI applications are easy to write through Python, in which TraCI can be imported as a Python module containing Python versions of every TraCI command.

2.2 Related Work

Many academic papers and governmental agencies have attempted to address the design and application of dynamic emergency response and traffic management systems. In fact an adaptive system is already being put into place by the New Jersey Meadowlands Commission (NJMC) which received $10 million grant from the New Jersey Department of Transport to incorporate 144 traffic signals into a self-adaptive network [21]. This network, dubbed MASSTR (Meadowlands Adaptive Signal System for Traffic Reduction), is due to be completed over the year 2014 and is expected to serve approximately 3 million vehicles daily. It is predicted to save 1.2 million hours in vehicle delays and 1.2 million litres of gasoline as well as reducing greenhouse gas by more than 11,000 tons per annum. While this is the only system currently being put into place many systems have been designed, especially in terms of the management of traffic lights.

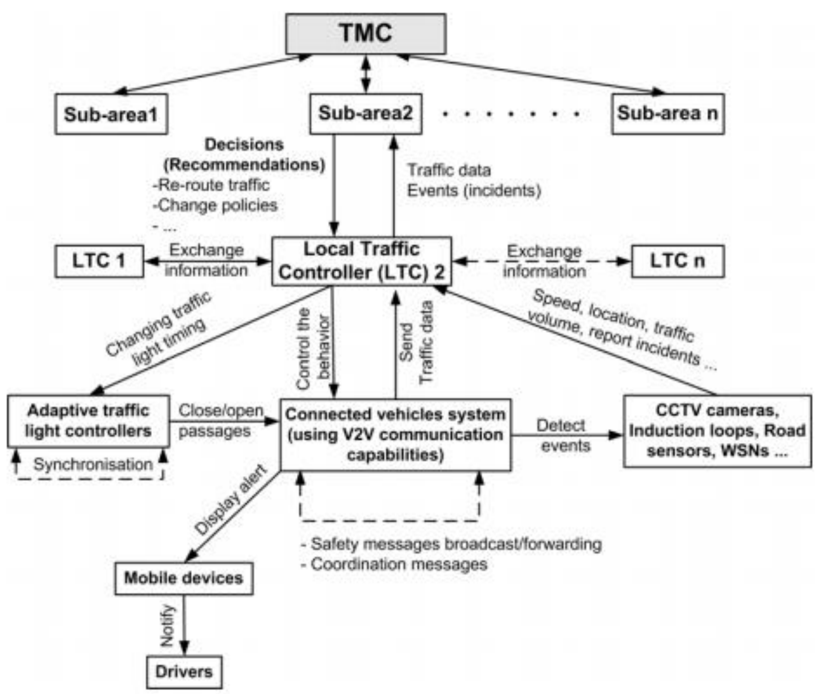

Figure 2.2.1 Example of an Adaptive TMS Architecture [22]

This project builds above the architecture an Adaptive TMS proposed in a paper titled *Adaptive Traffic Management for Secure and Efficient Emergency Services in Smart Cities* by Soufiene Djahel *et al* [22]. This paper outlines a theoretical system architecture for an adaptive TMS deployment with a view to reduce latency of emergency response vehicles by making projects such as this one feasible. The framework of the intended TMS, shown in Figure 2.2.1, consists of a Traffic Management Controller (TMC) which splits a large area (conceivably based on approximations of pre-existing district boundaries, e.g.: D1, D2…, D24. in Dublin) into heterogeneous sub-areas with each sub-area controlled by a Local Traffic Controller (LTC). The TMC can send decisions or recommendations to the LTC's if driving policies need to be changed or re-routing needs to occur and receives data on traffic levels and incidents (i.e. crashes) on which its decisions depend on. In the sub-areas themselves the LTC's supervise the adaptive traffic light controllers, connected vehicle systems which make use of V2V and V2I and all road monitoring technology such as WSN (Wireless Sensor Networks), CCTV cameras, road sensors and induction loops. The road monitoring equipment is responsible for feeding information on traffic and potential incidents to the LTC, however a crashed V2I enabled vehicle is capable of notifying the LTC directly about an incident. If the TMC requests a change in policies or rerouting the LTC can send messages to vehicles using V2I to notify and direct them regarding the TMC's decision, similarly, the LTC can communicate with traffic lights and order them to switch phases or extend certain phase duration based on local traffic data from the road monitoring installations.

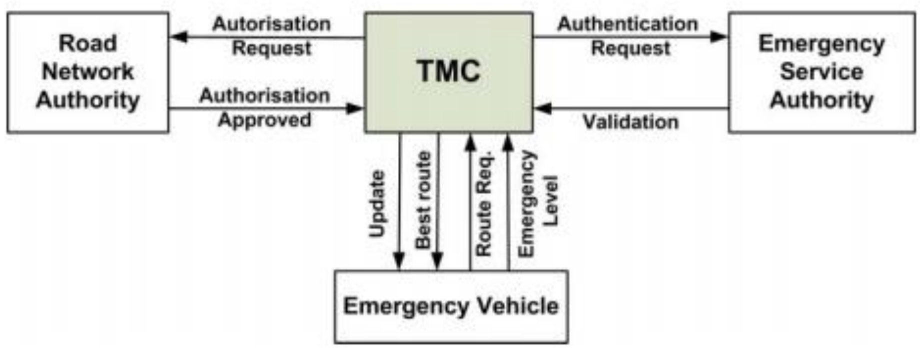

Figure 2.2.2 Emergency Response facilitated by TMC [22]

In the event of an incident, whichever emergency service authority aiming to dispatch an emergency vehicle (hospital, police, fire department etc.) announces it to the TMC, which in turns asks for an authentication request to stop unauthorised institutions or individuals from exploiting the system. The TMC will validate this and request authorisation from the Road Network Authority (RNA). Upon approval from the RNA the emergency vehicle informs the TMC of the Emergency level (i.e. the gravity of the incident A life-or-death situation will have a high emergency level than a non-fatal injury) and the route requirements. The TMC allocates it the best route based on both distance and the traffic information gained from LTC's and continues to update the route dynamically to cope with any potential change in circumstance. The emergency vehicle itself must of course be equipped with V2V and V2I technology to enable communication with the LTC's and to transmit information which may be vital for TMC decisions The TMC has the capability to make changes to driving policies or implement re-routing if necessary to facilitate speedy and safe arrival. Section IV of the paper gives a concise overview of the planned research necessary for the realisation, simulation and evaluation of the proposed adaptive TMS. The research plan involves protocols and security measures for V2V and V2I communications (which will likely depend on the robustness of the IEEE 802.11p protocol), selecting a proper decision making process for emergency response (which is covered in this project), and to investigate both the effect of human adaptation to the system and alternative methods of data collection as a failsafe against faulty or inaccurate road monitoring technology.

There exist many publications detailing adaptive mechanisms for traffic light control [23-25], all of these aim to dynamically change phases shift and duration of traffic lights rather than using fixed cycles by using WSN's and other road sensors to establish such factors as queue length, average crossing speed, traffic volume etc. to make decisions on how traffic lights should be altered. In [23] the proposed solution involves analysis of movements and queues denoted by cardinal map directions (e.g. traffic moving East-West through a light would have an EW movement), a conflict matrix is kept of all possible movements to know which are simultaneously permissible in any phase. Sensors are located at traffic light and at a certain distance (5-8 vehicle lengths) before them on incoming lanes to keep a count of departures and arrivals in a traffic queue to quantify queue length. The top layer of their intended system uses queue length and movement conflict data in conjunction with the waiting times of disjoint queues to calculate candidate phases, make a selection and determine the 'green time' before finally sending its decision back to the traffic light controller. In [24] a green light sequence determination algorithm takes six impact factors (traffic volume, waiting time, number of stops, hunger level, blank circumstance and special circumstance) deduced from a WSN of local and neighbouring traffic lights. Lastly the authors of [25] propose similar system but with a different view, their aim is to address the red-light running phenomenon where motorists attempt to cross lighted junctions in transitions between phases which causes accidents. Their system is akin to that in [24], using a WSN and road monitoring equipment consisting of Reduced-Function Devices (RFD) every twelve metres and Full-Function Devices (FFD) every sixty metres which analyse the cluster of RFDs and send on information to a First Pan Controller (FPC) which contains a dynamic Traffic Light manager which evaluates the situation and outputs a decision. The evaluation is based on subsections of road bounded by vehicle lengths, the total road segment length and approximate crossing speed. A lot of effort goes to quantifying the length of queues defining them as normal, medium or long as a function of road length over the subsections of road length. All three papers have tested their solutions using simulators and demonstrated an improvement in average waiting time and queue management. This project involves the management of traffic light phases but expands on the solutions in these papers by allowing for changes not only in light phases but also in driving policies and can be applied across a route rather than at a single intersection.

In *A Fuzzy Decision Support System for Traffic Control Centres* [26] a Traffic Decision Support System (TDSS) which tackles non-recurrent congestion regularly caused by vehicular accidents with a fuzzy case-based system. The system analyses the state of a network in terms of factors such as traffic density and average speeds as well as optimisation criteria such as desired minimal waiting time and maximal throughput to output a ranked list of optimal control measures which involve alterations to driving policies (lane closures, ramp metering etc.). The system has a fuzzy logic base of disparate cases. Cases considered consist of tuples in the form (b_i, c_i, Jsub (b_i, c_i)) where b_i is the *i*th element of b which contains vectors of network information, c_i is the *i*th element of c which contains vectors of control measures and Jsub is a function of weighted performance indices (e.g. predicted queue length, total travel/waiting times) which quantify the predicted effect of the control measures in c_i to the given traffic parameters specified in b_i in terms of efficiency. The weighted performance index used to evaluate cases is not necessarily fixed, the paper suggest that the weights could be changed on-line by a human operator in a traffic control centre. Since there exists an excessively high amount of possible cases in this form it is not tractable to evaluate all combinations with any traffic simulation. For this reason fuzzy logic is used, the fuzzy knowledge base contains a subset of possible cases and uses a membership function to make decisions on cases not explicitly stated in the knowledge base by deciding which case(s) are most similar to the input. The membership function returns a value between 0 and 1 for each case related to the input case to measure similarity where a value of 1 means the cases are identical and 0 means they are entirely disjoint. This means that unlike conventional case-based evaluation we are not mapping a fixed solution to a fixed case, allowing for a more fluid and adaptable system. A prototype of this system exists where all cases are based on traffic simulations, once this system operates in a legitimate traffic control centre cases may need to be updated to match real-world situations more accurately. This is very close to the work done in this project as a fuzzy logic system will be used to measure congestion levels, however this system does not intend to utilise V2X communications but rather Variable Message Signs to relay information to motorists. Furthermore this system aims to tackle congestion caused by emergencies rather than specifically reduce latency for emergency systems which is the primary goal of this project, with congestion control being the second priority.

3 Proposed Solution

3.1 Solution Outline

To solve the problem of emergency vehicle latency this project proposes the use of a TMS architecture akin to the one discussed in [22] capable of detecting incidents and adapting driving policies to cope with the emergency in question. The system uses a congestion level (CL) which is coupled with an Emergency Level (EL) (defined by the gravity of the emergency) to decide on a set of Emergency Response Procedures (ERP) to be applied on the route where the emergency vehicle is being dispatched. The congestion level is decided by a mechanism that uses a fuzzy logic function which combines certain weighted inputs: Lane Occupancy (LO), Average Vehicle Speed (AVS) and Estimated Time-based Demand (ETD), to decide on a Congestion Value (C) between 0 and 1 (or 0% and 100% congestion) which is mapped to a CL value. This involves a fuzzy membership function on each of the inputs followed by a defuzzification process to decide on an output value, this allows for dealing with more ambiguous traffic situations fluidly rather than having rigid and potentially flawed rules defining what constitutes a particular traffic level.

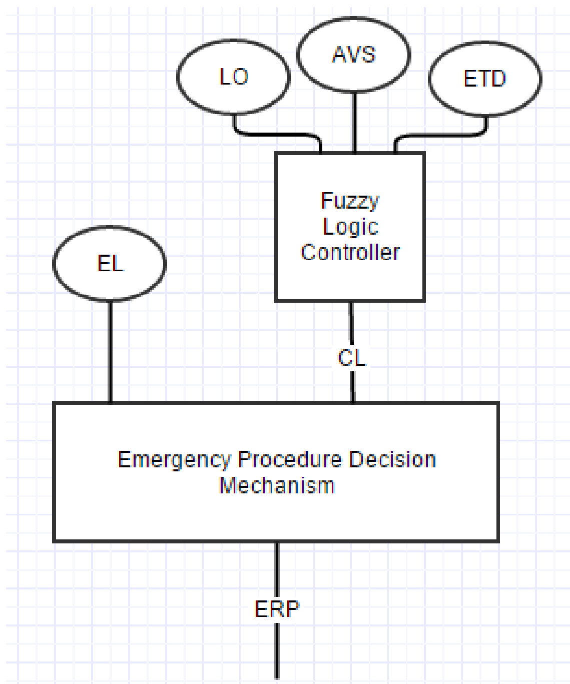

Fig 3.1 Emergency Procedure decision making process.

The diagram above is a visual representation of how decisions are to be made by the system. Further inputs may be added or the existing ones modified upon revision by Medical, Traffic and Emergency Response professionals. The output set ERP will contain a list of changes to be made to the road network, these include lane clearance, traffic light phase alteration, temporarily allowing the use of reserved and/or turning lanes, temporary raising of local speed limit and re-routing of vehicles. Once this system is ready for implementation it will be evaluated using SUMO and TraCi.

3.2 Research Plan and Timeline

Thus far in the project I have familiarised myself with both SUMO and TraCi as well as having undertaken a lot of background research in traffic simulation, V2V and V2I technologies as per the mandatory aspect of the project specification. Furthermore I have designed a majority of the required mechanism as outlined in section 3.1. To familiarise myself with SUMO and TraCi I undertook a diverse array of tasks (some by the direction of my mentor Soufiene and some at my own discretion) such as creating my own simple network and simulation, generating a uniform size grid and importing two Open Street Map (OSM) format networks into SUMO. The documentation for TraCi was rather dense and it took a while to find the Python documentation I needed to start writing programs which altered the traffic simulation. I have written a Python program which uses TraCI to detect a single crash in a SUMO simulation, dispatch an emergency vehicle from a random entry point, trace the emergency vehicle's route printing certain information to command line whenever a new edge is reached (such as edge number, next green light id and distance etc.) and ensuring the next traffic light the emergency vehicle will reach is set to green. This served not only to familiarise myself with TraCi but also gave me a base to implement and evaluate the mechanisms designed since they will need this functionality. The program was tested on a ten by ten network grid as well as on an imported OSM network of downtown Ottawa, the final solution will also be initially tested on the grid and later on Ottawa and lower Manhattan.

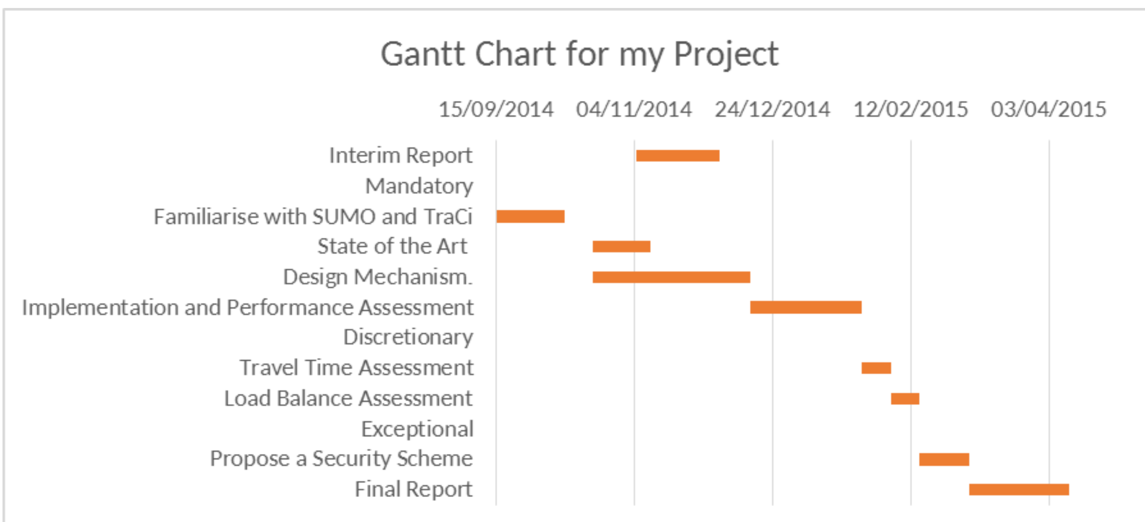

Fig 3.2 Gantt chart for my Project

Above is a Gantt chart detailing the progress made so far and the planned research timeline. As mentioned the design aspect of the mandatory section is near completion but given the upcoming examinations I have given a conservative estimate of the 16th December for the completion of this task allowing roughly thirty free days to finish the mandatory section of my project by the end of the first week of term in semester two. The discretionary tasks for this project involve the analysis of the implemented system on traffic load and journey times and will follow naturally from the final stages of the mandatory tasks which require evaluation of speed-up in emergency vehicle response time. Ideally the discretionary tasks could be started ahead of schedule allowing me to fine-tune the implemented system to increase performance while still having sufficient time to finish the exceptional objectives of the project. However if I feel the main solution can still be improved to a significant degree less time will be dedicated to designing a security protocol as finding a robust solution is my primary goal.

4 Bibliography

[1] Doug Payne (2000) *Poor ambulance response causes 700 deaths annually in Ireland*, British Medical Journal. Nov 11, 2000; 321(7270): 1176.

[2] L. Charles Smeby Jr (2013) F*ire and Emergency Services Administration: Management and Leadership Practices* Second Edition, April 2013 (pp 141)

[3] FDNY *Annual Report 2012/2013*
http://www.nyc.gov/html/fdny/pdf/publications/annual_reports/2012_annual_report.pdf

[4] NFPA, *National Fire Prevention Agency fire statistics in the US*
http://www.nfpa.org/research/reports-and-statistics/fires-in-the-us

[5] Karter, Michael J., Leblanc, Paul R. (1999). *Firefighter Injuries*. NFPA Journal, pp. 48-49.

[6] Liam Mulligan (2010), *Smart Cities and Sustainable Technology* Siemens Ltd. 2010 http://www.seai.ie/News_Events/Previous_SEAI_events/The_role_of_Smart_Cities_/Liam%20Mulligan%20,%20Siemens.pdf

[7] Benedikt Klotz (2011) *Emergency Management Solutions in Smarter Cities* IBM Corporation 2011 http://www-05.ibm.com/tr/events/ibmcozumlerzirvesi2011/pdf/Benedikt_Klotz.pdf

[8] Rudolf Giffinger, Christian Fertner, Hans Kramar, Robert Kalasek, Nataša Pichler-Milanović, Evert Meijers (2007) *Smart Cities Ranking of European medium-sized cities* , Centre of Regional Science, Vienna UT, October 2007

[9] *Smart Cities to Rise Fourfold in Number from 2013 to 2025* IHS Pressroom Tuesday, July 29, 2014 9:00 am EDT

[10] *A Communications-oriented Perspective on Traffic Management Systems for Smart Cities: Challenges and Innovative Approaches* Soufiene Djahel, Ronan Doolan, Gabriel-Miro Muntean and John Murphy. Nov 2013

[11] http://www.scoot-utc.com/

[12] http://www.scoot-utc.com/GoogleMap.php?menu=GoogleMap locations of SCOOT systems

[13]http://iris.dot.state.mn.us/

[14] http://www.511ga.org/

[15] *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application* NHTSA, U.S Dept. Of Transportation. DOT HS 812 014

[16] NHTSA press release Monday February 3 2014
http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles

[17] NHTSA (2010) *Frequency of Target Crashes for IntelliDrive Safety Systems* October 2010, DOT HS 811 381, (pp VI)

[18] *NXP Becomes World's First Supplier to Deliver V2X Chipset for Mass-Production Secure Connected Cars* NXP Press Releases, September 30 2014. http://www.nxp.com/news/press-releases/2014/09/nxp-becomes-worlds-first-supplier-to-deliver-v2x-chipset-for-mass-production-secure-connected-cars.html

[19] *SUMO – Simulation of Urban Mobility* (2011) Michael Behrisch, Laura Bieker, Jakob Erdmann, Daniel Krajzewicz. Institute of Transportation Systems, German Aerospace Centre.

[20] *TraCI: An Interface for Coupling Road Traffic and Network Simulators* Axel Wegener, Michał Piorkowski , Maxim Raya, Horst Hellbruck , Stefan Fischer and Jean-Pierre Hubaux CNS '08

[21] http://masstr.njmeadowlands.gov/

[22] *Adaptive Traffic Management for Secure and Efficient Emergency Services in Smart Cities* Soufiene Djahel, Mazeiar Salehie, Irina Tal, and Pooyan Jamshid. Work in Progress session at PerCom 2013, San Diego (19 March 2013)

[23] *A Distributed Algorithm for Adaptive Traffic Lights Control* Sebastien Faye, Claude Chaudet, Isabelle Demeure, 2012 15th International IEEE Conference on Intelligent Transportation Systems Anchorage, Alaska, USA, September 16-19, 2012

[24] *Adaptive Traffic Light Control of Multiple Intersections in WSN-based ITS* Binbin Zhou, Jiannong Cao and Hejun Wu. Department of Computing, The Hong Kong Polytechnic University, Hong Kong, Department of Computer Science, Sun Yat-sen University, China.

[25] *A Dynamic Traffic Light Management System Based on Wireless Sensor Networks for the Reduction of the Red-Light Running Phenomenon* Mario Collotta1, Giovanni Pau Gianfranco Scatà, Tiziana Campisi Faculty of Engineering and Architecture Kore University of Enna, Cittadella Universitaria, 94100 Enna, Italy.

[26] *A Fuzzy Decision Support System for Traffic Control Centres* A. Hegyi, B. De Schutter, S. Hoogendoorn, R. Babuska, H. van Zuylen, and H. Schuurman. Proceedings of the 2001 IEEE Intelligent Transportation Systems Conference (ITSC'01), Oakland, California, pp. 358–363, Aug. 2001.

[27] *Smart America Challenge Advanced Vehicular Communications*, © 2014 Qualcomm Technologies, Inc. (pp. 19).
http://smartamerica.org/wp-content/uploads/2014/05/SmartAmericas-Advanced-Vehicular-Communications-061114-final.pdf

[28] *Plug-In Vehicle to Home (V2H) Duration and Power Output Capability*, David P. Tuttle, UT MicroGrid Rodeo February 20th, 2014.
http://www.utexas.edu/research/cem/RODEO%20Pres/TUTTLE%20Presentation.pdf