Development of Portable Air Quality Index (AQI) and Emergency Vehicles Preemption Prototype Based on Internet of Mobile Things (IoMT)

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ABSTRACT
The technological advancements of the Internet of Things (IoT) in the recent past have facilitated immense progress towards mitigation of environmental pollution through smart transportation systems and solutions. In particular, communication to the commuters about the traffic ahead or occurrences of congestion has been envisioned to play a major role in outsmarting traffic through mobile applications giving rise to the emergence of the Internet of Mobile Things (IoMT). However, the existing mobile applications that serve as traffic reporting solutions still face major issues such as fixed route suggestions, longer delays during busy hours or emergencies, inefficient prompting of road accidents and heavy traffic en route to a particular destination. This research aims at providing solutions for notifying the commuters with updates on the traffic based upon the Air Quality Index (AQI) of the routes towards the destination and also about the approach of emergency vehicles. The cross-platform mobile application in this way enables the user to opt for a route with good air quality so that the more congested routes are avoided thereby mitigating the air pollution induced by road traffic. The experimental testing and validation of the proposed methodology are applied for areas belonging to Greater Kuala Lumpur. The various timings divided according to peak and non-peak hours are experimentally tested for analyzing the parameters of traffic usage and pattern through the mobile application. The outcome of the experiments has showed that when traffic flow is modelled and governed through vehicular emissions and concentrations of air pollutants, nearly 75% of the congested traffic is reduced thereby, giving rise to pollution-free environment as well as mitigation of urban heat island (UHI) effect that is formed through vehicular heat generation and difference in temperatures. On the other hand, the approach of emergency vehicles also prompts the commuters to avoid panic.

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CCS Concepts
• **Hardware→Emerging tools and methodologies.**

Keywords
Air quality index; Air pollution; Road transportation; Internet of Things and traffic congestion.

1. INTRODUCTION
In the past few decades, the population of vehicles has been on higher demand. This huge demand for vehicles results in heavy traffic congestion, accidents, pollution and costs millions of dollars for annual fuel consumption. Such drawbacks have led researchers to look for effective solutions to mitigate vehicular traffic congestion. The vehicular network environment is dynamic in nature due to the frequently changing topologies and network configurations. Though there are numerous existing Intelligent Transportation Systems (ITS) techniques comprising of Internet of Things (IoT) and Vehicular Adhoc Networks (VANETs), which enables the users to keep well-informed and well-updated about smarter ways to deal and handle utilization of transport networks, seldom do they provide guarantee for considering non-recurring congestion as well as means for mitigation of traffic congestion induced air pollution and fuel consumption.

Moreover, the long waiting hours of vehicles at signals and traffic jams leads to higher air pollution levels and heat generated from vehicular exhausts cause Urban Heat Island (UHI) effect. The developing countries like Malaysia, still face potential drawbacks such as increased air pollution levels, due to higher vehicle usage rate resulting in adverse health hazards such as respiratory diseases and asthma. *In this research, the Air Quality Index (AQI) values obtained using the deployment of real-time AQI measuring* *devices, are validated with existing system's values for performance comparison and traffic management.*

The proposed cross-platform mobile application is developed on iOS and Android platform at the application layer for timely updates on the AQI values and is also based on the approach of emergency vehicles to the end users. AQI here refers to the numerical value assigned to the level of air quality in the atmosphere. These values are communicated to the commuters tailored to the traffic pollution levels of various routes towards the destination in a timely manner. This concept is based upon an IoT based protocol and is envisioned as an application of the Internet of Mobile Things (IoMT).

Figure 1. Internet of mobile things (IMoT).

The future of smart transportation relies upon the 5G communication as per the IoT researchers and such applications of IoMT would pave a way for the extensive implications of higher mobility, lower latency and spectral efficiency of 5G networks as depicted in Figure 1.

2. LITERATURE REVIEW

In a timespan of the past few decades, vehicular use and population have been tremendously increasing around the world. The usage of a huge number of vehicles cause heavily congested traffic, increased fuel consumption, higher air pollution and the resultant economic hazards [13]. These reasons are the major contributors to global warming. The fast-growing utilization of vehicles gives rise to environmental threats with regards to harmful CO_2 emissions. A study by [5] suggests that emission levels in Malaysia according to CO_2 projections between the years 2000 to 2020 is estimated to increase by 68.86%. This rapid increase in percentage shows that almost 3 billion tons of harmful CO_2 emissions will be released during the year 2020 if no preventive measures are taken for pollution mitigation systems.

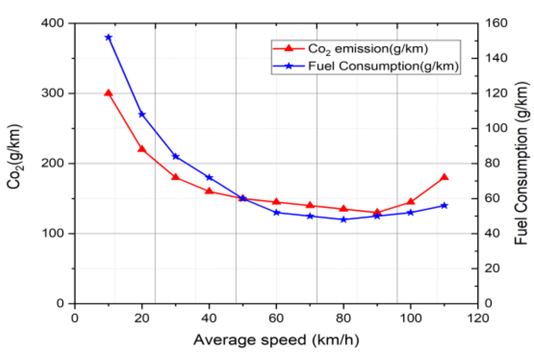

Figure 2. Fuel Consumption vs CO_2.

Over the last years, road traffic congestion and the associated emissions have drawn lots of attention in environmental related research. Based on results contributed by [8] the CO_2 emissions and rate of fuel consumption are directly impacted due to traffic congestion. Therefore, for better solutions to address environmental issues, it is essential to find an optimal relationship between travelling speed of vehicle and rate of fuel consumption along with CO_2 emissions. There is a considerate amount of numerical representations that relate the fuel consumption rate with travelling speed of vehicles and CO_2 emissions in the past few decades.

The representation in Figure 2, depicts such parameters as a function of average travel speed. It clearly shows that there is a 30% average increase in CO_2 emissions and fuel consumption at low average travel speed due to severe vehicular congestion and longer delays at signals (increase in stop-and-drive mode and idle engine extension). Moreover, at relatively higher speeds also there is higher CO_2 emissions and fuel consumption due to the need for more power to the vehicle engine. An average moderate travelling speed that typically ranges from 65 to 85 Km/h produces comparatively lower CO_2 emissions and fuel consumption. Hence, it is essential to mitigate these greenhouse gases and CO_2 emissions by switching towards a fleet that requires lesser stop and drive mode of driving with fewer idle time. Therefore, the solution for effective measures with a reasonable cost for vehicular congestion mitigation and preservation of the environment is essential to reduce the rate of fuel consumption and emission of harmful pollutants [1].

The solution of raising new buildings and highways with higher capacities can be employed to address the above-mentioned issues but can turn out to be cost inefficient, time-consuming and space-limited. Additionally, the research development and innovation on switching towards alternative fuels tend to consume a lot of time and effort to turn to a reality [4,12]. The giant vehicle manufacturers have made significant contributions towards enhancing the design of vehicles and developing the features of cost-effectiveness, environment-friendliness and fuel consumption. The green technology-based solutions have rather given importance to the interior features and technology of the vehicles, for instance, the vehicular companies that focus on research and development to make economical and environment-friendly engines. Few examples of such efforts are fully electric and hybridized vehicles [6,10]. Comparatively, the optimal utilization of the existing streets and roads can mitigate the congestion issue at a reasonable cost in larger metropolitan cities.

Nevertheless, such solutions require exact information about the present status of the streets and roads that turns out to be a challenging risk due to rapid changes in vehicular environments and networks. Intelligent Transportation System (ITS) is defined as a novel emerging platform that combines the electrical technology and network-oriented information with transportation-based technologies [7,11]. This framework covers and addresses a huge variety of methodologies and techniques such as intelligent embedded systems to mitigate the rate of fuel consumption and CO_2 emissions. Such techniques can range from an application-based traffic light signals, traffic routing methodology or even the system for electronic toll collection at highways. These ITS techniques address the mitigation of fuel consumption based on 2 aspects- firstly, to suggest alternate paths with shorter time period rather than shorter distance paths and secondly to mitigate the traffic congestion that maintains optimal vehicle speed [9]. According to [14], the two most promising solutions for mitigation of CO_2 emissions and fuel consumption rate are – Vehicular traffic routing system (VTRS) and ITS based traffic light signals (ITLS).

Comparatively, the former is considered to be a better solution than the latter due to cost factors and time consumption. Nevertheless, majority of the current VTRS methods have obtained a better outcome for cutting down the travel time or for improved flow of traffic, they can seldom provide assurance for mitigation of fuel consumption, air pollution and noise [2,3]. Therefore, this research aims to develop smart traffic congestion mitigation model based on the values of air quality index (AQI) and prompting of emergency vehicles. This solution is based upon governing the flow of traffic based upon the AQI values, so that the vehicles are routed in the paths with lesser AQI (green paths). The term "green path" here refers to those routes with relatively lesser traffic congestion, reduced fuel consumption and CO_2 emissions.

3. MOBILE APPLICATION FRAMEWORK

The proposed methodology comprises of the data gathering mechanism and distributive path guidance suggestion among vehicles in vehicular networks. These networks are highly dynamic in nature and comprise of unique characteristics such as constrained resource availability and distributed radio channel. They also have issues such as the absence of central coordination, the insecure medium of communication and the hidden terminal problem. The proposed methodology is evaluated in terms of its performance through a cross-platform mobile application called "Go Green Malaysia". The real-time AQI measuring devices are installed in various areas of Greater KL, followed by which extensive simulations run and tests are done to evaluate the proposed approach in comparison to other existing methods. The distinctive scenarios with different sizes of maps, AQI values, vehicular densities, accident and weather conditions are taken into account for comparative analysis between the existing and proposed solutions.

The proposed methodology comprises of an IoT based mobile application and is aimed towards modelling the heavily congested road traffic to mitigate congestion as depicted in Figure 3. The traffic induced air pollution causes the emission of harmful pollutants into the atmosphere ultimately leading to higher AQI. Therefore, prompting the users with notifications of routes having lesser AQI, can considerably mitigate the longer delays, traffic congestion and can also address an increased percentage of harmful emissions into the atmosphere. The parameters for performance evaluation include pollutant emission level, UHI effect and vehicular density ratio.

The comparative analysis with respect to the existing solutions is carried out for the results of performance determination. The application is developed on iOS and Android platforms using Apache Cordova and Ionic framework at the application layer, for timely updates on the AQI. The application shows the different routes with the AQI information wherein the user inputs the current location and destination address as shown in Figure 4, after which the selection of route with lesser AQI is chosen for the commuter to reach the destination through less congested route and also the approach of emergency vehicle, as depicted in Figure 5, ultimately resulting in balance of air pollution levels and mitigation of traffic-induced pollution. The experimental validation and analysis of the proposed methodology are carried out for different areas of greater KL, in Malaysia as part of the extension of the research presented in [15,16]. The various timings of the day (morning, afternoon and evening) are monitored for evaluation and explored for the usage of traffic parameter based on the mobile application.

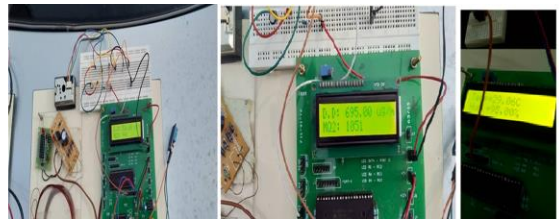

Figure 3. The proposed proof-of-concept (POC) for monitoring of air quality.

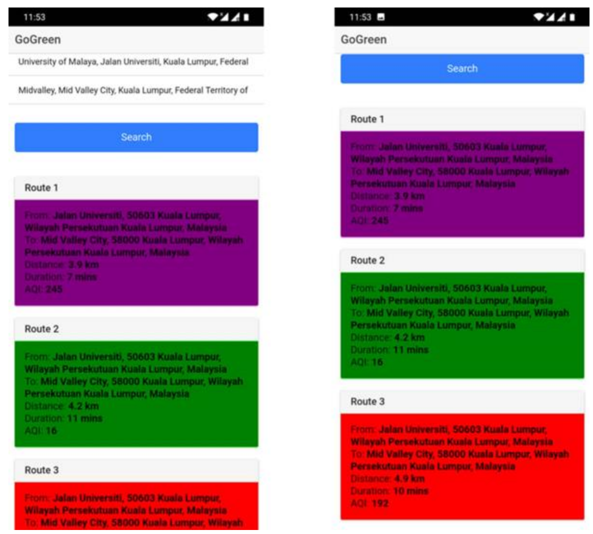

Figure 4. Screenshot of the proposed mobile application showing the route suggestions.

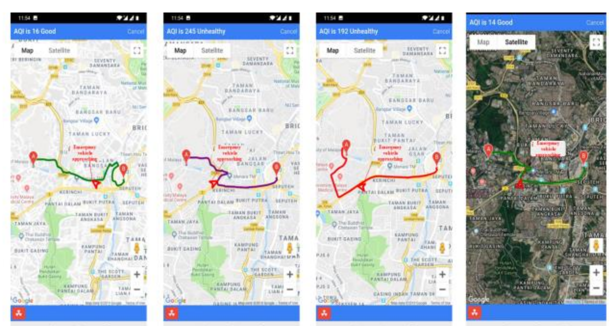

Figure 5. The proposed mobile application showing AQI of the routes with the approach of emergency vehicles.

4. CONCLUSION

The correlation between pollutant emission, the flow of traffic and dispersion of harmful gases into the atmosphere determines the quality of air and enables a broader scope for designing the traffic management methodologies for urban road networks. The proposed methodology has determined that modelling the flow of road traffic based on AQI has consequently mitigated the air pollution level. It can be said that whenever, the traffic flow and vehicular emission are integrated together, the rate of harmful emissions are estimated to be better for ensuring good air quality of urban transportation. The development of proposed methodology has revealed that the major contributions of air quality are – traffic flow, speed/acceleration of vehicles, vehicular density, an average waiting period of vehicles at junctions/intersections, type of air pollutant and frequency of stop and drive mode in vehicles. The results are experimentally analyzed and quantified for various urban road networks and traffic management scenarios. The experiments have provided an essential perspective for enabling pollutant free atmosphere and also to mitigate the traffic congestion. The proposed traffic-induced air pollution mitigation mechanism proves that nearly three-fourths of the emissions into the atmosphere can be alleviated by reducing the heavy congestion due to long delays and heavier densities of vehicles. The preemption of emergency vehicles on one hand, can save human lives through faster transportation (such as for ambulances) and on the other hand, can alleviate panic caused to the on-road commuters as well.

The future work is focused upon improvising the mobile application for bugs identified and also to include the notifications about the places of interest as per recommendation systems for the route suggestions provided to the user.

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6. REFERENCES

[1] Ahmed, M. et al. (2013) Vehicle Adhoc Sensor Network Framework to Provide Green Communication for Urban Operation Rescue, Lecture Notes on Information Theory, 1(2), pp. 7782. DOI: 10.12720/lnit.1.1.77-82

[2] Akcelk, R., Smit, R. and Besley, M. (2012) Calibrating Fuel Consumption and Emission Models for Modern Vehicles, IPENZ Transportation Group Conference. DOI:261363189

[3] Bakhouya, M., Gaber, J. and Lorenz, P. (2011) An adaptive approach for information dissemination in Vehicular Ad hoc Networks, Journal of Network and Computer Applications. Elsevier,34(6), pp. 19711978. doi: 10.1016/j.jnca.2011.06.010.

[4] Barth, A. and Boriboonsomsin, M. (2009) Traffic Congestion and Greenhouse Gases, Access Magazine, 35. Available at: http://www.accessmagazine.org/fall-2009/traffic-congestion-greenhouse-gases/

[5] Demestichas, K. et al. (2011) Intelligent Advanced Driver Assistance System for Electric Vehicles, 2011 IEEE Intelligent Vehicles Symposium (IV), (Iv), pp. 7882. doi:10.1109/IVS.2011.5940409.

[6] Dimitrakopoulos, G. and Demestichas, P. (2010) Intelligent Transportation Systems, IEEE Vehicular Technology Magazine, 5(March 2010), pp. 7784. doi: 10.1109/MVT.2009.935537.

[7] Frey, H. C. et al. (2003) On-road measurement of vehicle tailpipe emissions using a portable instrument, Journal of the Air and Waste Management Association, 53(8), pp. 9921002. doi:10.1080/10473289.2003.10466245.

[8] Jabbarpour, M. R. et al. (2014) Cross-layer congestion control model for urban vehicular environments, Journal of Network and Computer Applications, 44, pp. 116. doi: 10.1016/j.jnca.2014.05.002.

[9] Jianmin Jiang; James Charles; Konstantinos Demestichas (2011) Toward Cooperative and Intelligent Optimization of Travel Planning and Energy Saving for Drivers of Fully Electric Vehicles, (SEPTEMBER), pp. 2226. doi: 10.1109/MVT.2011.941900

[10] Martinez, F.J., Fogue, M., Toh, C.K. et al. (2013) Computer Simulations of VANETs Using Realistic City Topologies Wireless Pers Commun, 69: 639. https://doi.org/10.1007/s11277-012-0594-6

[11] Van Mierlo, J. et al. (2004) Environmental rating of vehicles with different alternative fuels and drive trains: A comparison of two approaches, Transportation Research Part D: Transport and Environment, 9(5), pp. 387399. https://doi.org/10.1016/j.trd.2004.08.005

[12] Narzt, W. et al. (2010) Self-organizing congestion evasion strategies using ant-based pheromones, IET Intelligent Transport Systems, 4(1), pp. 93102. doi: 10.1049/iet-its.2009.0022.

[13] Papadimitratos, P. et al. (2009) Vehicular Communication Systems: Enabling Technologies, Applications, and Future Outlook on Intelligent Transportation, IEEE Communications Magazine, (November), pp. 8495. doi: 10.1109/MCOM.2009.5307471.

[14] Salvi, B. L., Subramanian, K. A. and Panwar, N. L. (2013) Alternative fuels for transportation vehicles: A technical review, Renewable and Sustainable Energy Reviews. Elsevier, 25, pp.404419. https://doi.org/10.1016/j.rser.2013.04.017

[15] Schrank, D., Eisele, B. and Lomax, T. (2012) TTI s 2012 Urban Mobility Report Powered by INRIX Traffic Data TTI s 2012 Urban Mobility Report Powered by INRIX Traffic Data, Report, Texas A&M Transportation Institute. The Texas A&M University System, (December). Acc. no. 01579161

[16] Anjum, S. S., Noor, R. M., Aghamohammadi, N., Ahmedy, I., Kiah, M. L. M., Hussin, N., Qureshi, M. A. (2019). Modeling Traffic Congestion Based on Air Quality for Greener Environment: An Empirical Study. IEEE Access, 7, 1–24. https://doi.org/10.1109/ACCESS.2019.2914672.

[17] Shaik Shabana Anjum, Rafidah Md Noor, Ismail Ahmedy, Mohammad Hossein Anisi, Nasrin Aghamohammadi, Norazlina Binti Khamis and Muhammad Ahsan Qureshi, "Performance evaluation of energy-autonomous sensors for air quality monitoring in Internet of Vehicles", 1st International Workshop on Internet of Autonomous Vehicles (INAVEC) held in conjunction with IEEE 89th Vehicular technology Conference, 28 April- 1 May 2019, Kuala Lumpur, Malaysia. DOI: 10.1109/VTCSpring.2019.8746496.