EPIC – Emergency Vehicle Traffic Light Pre-emption in Cities

Public report

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Project within Traffic safety and automated vehicles

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Table of content

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1 Executive summary

“EPIC – Emergency Vehicle Traffic Light Pre-emption in Cities” is a continuation of the FFI pre-study “PEV - Platform for Communication with Traffic and Infrastructure from Emergency Vehicles. The main purpose of EPIC is to design and demonstrate a system, compliant with the European standardization effort, that allows emergency vehicles to send requests for green light pre-emption to signalized intersections. By eliminating the need for emergency vehicles to run red-lights at intersections, the system will be able to guarantee that a safe and fast passage would be facilitated.

The main research question can be summarized as follows: Is it possible to implement a traffic light preemption system working under the constraints of the NordicWay/C-roads standard that also complies with the security, safety and efficiency requirements already defined under the EU C-ITS standard. A prototype of the preemption system running on a simulated version as well as live version of the Interchange mechanism would be developed in order to answer this question.

Once viability was confirmed via experiments, the development of the system went into the production phase. At this stage, the system had to be integrated with the real Interchange (the newest version) allowing for successful testing on realistic scenarios in Sweden.

2 Background

“EPIC – Emergency Vehicle Traffic Light Pre-emption in Cities” is a continuation of the FFI pre-study “PEV - Platform for Communication with Traffic and Infrastructure from Emergency Vehicles. Results from PEV showed that red light running through signalized intersections is perceived as one of the most dangerous maneuvers for an Emergency Vehicles (EV). It is estimated that European EVs are involved in 88 000 traffic accidents yearly out of which 37 900 EV accidents happen in intersections. It is estimated that these accidents accounts for 164 deaths.

Traffic flow simulations have showed that if EVs where given green phase at signalized intersections the average trip time would be reduced by >10%. This means that a system for EV traffic light pre-emption has the potential of saving the European society €45bn yearly while improving traffic safety.

The purpose of EPIC is to design and demonstrate a system, compliant with the European standardization effort, that allows emergency vehicles to send request for pre-emption (green phase) to signalized intersections.

3 Purpose, research questions and method

The main purpose of EPIC was to design and demonstrate a system, compliant with the European standardization effort, that allows emergency vehicles to send requests for green light pre-emption to signalized intersections. By eliminating the need for emergency vehicles to run red-lights at intersections, the system will be able to guarantee that a safe and fast passage would be facilitated. It is anticipated that this will improve the safety of intersection crossing for EVs by more than 50%. Therefore, in Europe alone, the project has the potential of preventing more than 19 000 EV accidents yearly, saving hundreds of lives and millions to government agencies.

A defining feature of this project, one that greatly differentiates it from other traffic light preemption systems being tested around the globe, is derived from the unique nature of the Scandinavian standards for vehicular communications i.e., the NordicWay project. Unlike the decentralized nature of the European (C-ITS) or the

American (SAE) standards, the NordicWay framework is based on the used of a centralized messaging system called the *Interchange.* This introduces unique challenges related to communication, anonymity and security that are not present (or have already been solved) in other pilot projects around the world. This is in addition to also having to comply with the basic C-ITS requirements for V2X safety applications related to communication delay and throughput.

Taking the last two points into account, the main research question can be summarized as follows: Is it possible to implement a traffic light preemption system working under the constraints of the NordicWay/C-roads standard that also complies with the security, safety and efficiency requirements already defined under the EU C-ITS standard. A prototype of the preemption system running on a simulated version of the Interchange mechanism would be developed in order to answer this question.

To achieve this, it was necessary to develop a message encoder/decoder to generate and translate the required standard messages (*Signal Request* and *MAP* messages). Next, an Apache QPID server was set up to act as a local virtual version of the interchange (based on Ericsson's Interchange implementation) in order to manage subscriptions and monitor message exchanges, Finally, experiments were run using MAP data from the California Vehicle Testbed (due to lack of available local data).

Once viability was confirmed via experiments, the development of the system went into the production phase. At this stage, the system had to be integrated with the real Interchange (the newest version) allowing for testing on realistic scenarios here in Sweden. This required MAP data for the cities of Uppsala and Stockholm which was manually generated using open-source tools. The system also had to adapt to changes in the NordicWay specification for the traffic light preemption use case, more specifically, to the addition of *cooperative awareness messages* (*CAM*) to the application and changes in the flow of *MAP* messages. Final testing of the system will be performed in a real urban scenario around the city of Stockholm and/or Uppsala.

To further, statistically prove, the benefits of the solution traffic flow simulations was made. The VEINS framework was employed to test and validate the system, which combines the features of OMNeT++ development and graphical runtime environment with the SUMO traffic simulator. The simulation was used to evaluate the performance of the system, and the results obtained from the experiments. To ensure statistical significance, 100 different sets of background traffic were created.

4 Goals

The goals of the EPIC project were effectively disseminated both in the industrial and research environments. The main deliverable of the project should be a demonstration in relevant environment of traffic light pre-emption for emergency vehicles. The demonstration shall show-case an ITS application, that allows for a safe and efficient pre-emption/prioritization of traffic lights for an arbitrary intersection. As steppingstones, to the overall objective of the project, several sub-results should also be delivered:

- Simulation environment for EV traffic light pre-emption,
- Simulation results showing how to optimize the ITS application to maximize the positive impact in terms of reduced number of EV accidents and reduced EV response times,
- Optimized prototype ITS application for EV traffic light pre-emption,
- Relevant demonstration environment

5 Results and goal achievement

The traffic light preemption system was first tested using GPS data from sample trajectory for an emergency vehicle traveling back and forth through three real intersections (in California) while requesting traffic signal priority via the Interchange. The average trip time between these intersections ranges from 5 to 10 min depending on real-time traffic conditions. The traffic light controller TLC side of the communication was also simulated by sending signal response messages *(SSMs*) with different responses to the requesting vehicle in order to test the messaging system encoding and decoding of standardized SAE messages. The results were extremely promising, the system was able to decode geographic data from MAP messages and generate adequate SRMs on-demand using trajectory matching with real time navigation data. By using an adequate MAP database it is also possible to generate a green wave using trajectory matching on a sequence of consecutive intersections. Simulations show that providing the emergency vehicle with green phase at signalized intersections reduces average trip time by approximately 20% whilst increasing traffic safety by reducing the risk of collisions. Finally, the emergency vehicle can adjust its trajectory according to the received SSM status responses received from the TLC, while simultaneously, it can also update the TLC on unexpected trajectory changes by sending new SRM requests, updates or cancellations as needed.

After the preliminary results confirmed the viability of the system, full scale development of the system went ahead. The main difference between the prototype version and the production version is the full integration with the real Interchange mechanism as well as the inclusion of additional requirements for the traffic light preemption use case that weren't present in the initial specification of the NordicWay/C-roads standard. This time testing was performed using real-time GPS data from the Swedish cities of Uppsala and Stockholm. Once again, the results were positive, with the system able to perform according to the desired specifications under a myriad of traffic conditions. The functional specifications are being fulfilled.

To further prove the benefits of the systems more results were collected through traffic flow simulations. The experiments conducted yielded an average improvement in trip time of 30.15% and 71.66% in the proposed safety metric (time integrated time-to-collision indicator - TIT). The system closely adhered to the guidelines of ISO 19091, making it a powerful and adaptable solution for a variety of emergency scenarios. There were no instances of increased danger or time using the system. The results indicate that the system is highly effective and safe for real-life emergency scenarios.

6 Dissemination and publications

6.1 Dissemination of knowledge and results

How are/are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the area	X	Several publications have been made as part of the project.
Carried forward to other advanced technical development projects		
Forwarded to product development projects	X	Evam will utilize the project results for continued product development in the area.
Introduced to the market	X	Traffic signal priority will be introduced in Evam's market offering.
Used in Investigations/regulations/permit matters/political decisions		

6.2 Publications

Felipe Valle, Alexey Vinel, and Mikael Erneberg. 2021. Traffic Light Priority in NordicWay. In Communication Technologies for Vehicles: 16th International Workshop, Nets4Cars/Nets4Trains/Nets4Aircraft 2021, Madrid, Spain, November 16–17, 2021, Revised Selected Papers. Springer-Verlag, Berlin, Heidelberg, 49–55. https://doi.org/10.1007/978-3-030-92684-7_5

E. K. Duarte, L. A. L. F. Da Costa, M. Erneberg, E. P. De Freitas, B. Bellalta and A. Vinel, "SafeSmart: A VANET System for Faster Responses and Increased Safety in Time-Critical Scenarios," in IEEE Access, vol. 9, pp. 151590-151606, 2021, doi: 10.1109/ACCESS.2021.3126334.

7 Conclusions and continued research

The traffic light preemption system is currently undergoing testing on a real urban scenario using real time GPS data and a full implementation of the messaging system. Initial testing has shown promising results with the system being able to fulfill all the requirements specified on both the NordicWay/C-roads and the C-ITS standards. These include basic V2X communication requirements such as maximum latency (delay) of messages and more specific application related requirements such as anonymity of the vehicle users.

To increase the statistical evidence for the benefits of the system larger datasets collected from real life implementations are needed.

8 Participating parties and contact persons

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