Design of a Novel Road Traffic Control System for ZalaZONE Proving Ground

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Abstract

The testing of Connected and Automated Vehicles (CAVs) and that of the smart infrastructure (traffic control devices and vehicle sensors) in relation with CAVs will be supported by the development of a novel type of road traffic light management system at ZalaZONE Automotive Proving Ground. The system to be developed aims to allow a fully flexible traffic signal control during vehicle and system testing. The system shall provide a freely programmable open Application Programming Interface (API) towards the traffic light control units in contrast with traditional (rigid and closed) traffic control equipments. In this concept, each traffic light control unit will be made available via a remote control software running on a cloud system.

Keywords: road traffic control, traffic light, ZalaZONE

1 Introduction

The development is motivated by the favorable situation that a new, automotive proving ground was constructed in Hungary (Zalaegerszeg), called ZalaZONE (https://zalazone.hu/) \cite{1}. This test track is specifically designed for Connected and Automated Vehicle (CAV) as well as for Cooperative, Connected and Automated Mobility (CCAM) testing and homologation processes in the near future. The more, the mission of ZalaZONE is not limited to pure commercial use. It is also aims to actively support research and innovation activities in national and international cooperation both with academia and industrial partners.

In this research, a system is designed for a fully flexible road traffic control system at ZalaZONE Proving Ground where 7 signalized junctions are located at the Smart City Zone and 3 signalized intersections at the University Test Track. Additionally, a public road intersection in Zalaegerszeg city will be signalized in 2022, which shall be also controlled by the proposed traffic management system.

2 Traffic Light Control in the era of CAVs

Until now all realizations of traffic lights have been based on the fact that traffic signals are perceived by human drivers exclusively. Therefore, all relevant standards prescribe the technical requirements according to the capability of human perception, e.g. traffic lights' radiation angle \cite{2} or the position and number of traffic signal heads at the road crossing.

With the presence of automated cars the time has arrived to fundamentally rethink the classical approach concerning the production and operation of traffic light controllers. The goal of this technological revolution is the cooperation between the traffic controller and the vehicles, i.e. V2X (Vehicle to Everything) communication technologies. This can be realized in one-way or two-way communication:

- Traffic light controller provides messages to road vehicles which process the received information for their own purposes.
- Road vehicles communicate information to traffic light controller.
- The communication is bidirectional between the traffic controller and the vehicle.

In relation with the wireless technology, the technical specification for Signal Phase and Time and Map Data (SPaT/MAP) \cite{3} must be taken into consideration when talking about future traffic controller design. SPaT/MAP...
offers a potential channel for detailed information exchange between traffic systems and road users. Based on SPaT data the vehicles (or drivers) can be informed about the current status and change of the traffic signal ahead as well as about the next signal stage change. It also provides information about approaching traffic to optimize the signal system. MAP data describes the physical geometry of one or more intersections. In connection with SPaT/MAP the ISO/TS 19091:2017 norm [4] is also important to mention as it defines the message, data structures, and data elements to support exchanges between the roadside equipment and vehicles.

3 Traffic Control System Design for Test Track

The aim of the planned road traffic control is to enable a flexible system such that traffic signal heads (vehicle, bicycle, pedestrian and auxiliary signals) can be controlled even separately and freely during vehicle tests. The control of all traffic light at the ZalaZONE test tracks shall be made available by means of a central control software running in a cloud system. The basic concept of the designed system is illustrated in Fig. 1, where each traffic lights as well as traffic signal heads can be arbitrary controlled. A more specified architecture is shown by Fig. 2.

![Fig. 1 Overview of the ZalaZONE traffic light control system](image)

The central software controls the traffic light system via Kafka Messaging Protocol. Furthermore, the control center shall be made available to external systems via an open API too. This means that users might apply own (flexible) traffic control logic when testing, basically using “getter” and “setter” functions for traffic light operation.

![Fig. 2 System architecture of the traffic control](image)

The main requirements for the control system is defined as follows. The traffic light control system shall be freely programmable. All safety systems common in road traffic management systems (and required by standard originally) shall be flexibly switched on or off (i.e. when deactivated, there is no intergreen time matrix, no green conflict monitoring). The central control software shall also ensure that the signal heads are accessible at all times for verification: the software shall continuously check that the predetermined signal phases (even if intentionally irregular for testing purposes) are displayed on the light points and that the LED bulbs are not broken down.
The control center has three control modes:

- **Signal Control Script:**
  Operation according to a predefined sequence in a script file (a case of this is the conventional fixed-time program protected by intergreen time matrix).
- **Signal Control API:**
  Control implemented by commands from an arbitrary program (e.g. Matlab or Python script) via open API.
- **Signal Control GUI:**
  Control can be realized via a GUI. In practice, it means an arbitrary modification of the currently running program.

The hierarchy between the 3 control modes introduced above holds the following sequence. A Signal Control Script based control (1) can be overwritten by logic (2) via the Signal Control API or modified by control (3) via the GUI at any time. Additionally, a Signal Control API based control (2) can only be overwritten by an intervention through the Signal Control GUI (3).

In the designed system the following access levels are defined for users.

- Access level "admin" denotes access to every function and the development environment.
- Access level "tester" means access to every relevant function.
- Access level "researcher" is the access to every function.
- Access level "demo/viewer" means access to limited functions.

### 4 Software development via PLC devices

The central management software will be developed according to the predefined requirements: all light points shall be freely programmable in the system. This means that even all safety functions, which are used in traditional traffic light controllers according to the standards (e.g. intergreen time matrix checking), can be switched off while testing with adequate security measures. To realize this mission, proper controller devices are needed on the intersection spots. Therefore, at the signalized ZalaZONE intersections WAGO Programmable Logic Controllers [5] (PLCs, shown by Fig. 3) will be used for:

- local control of the traffic lights and
- allowing remote control from the central traffic management system.

![Fig. 3 Programmable Logic Controller (WAGO PFC200) for ZalaZONE signalized intersections (pictures from [5])](image)

The WAGO PLCs work on Linux based operation system allowing a fully flexible programming. On the one hand, a basic local program works on this type of PLC. On the other hand, in the background Linux programs can be run. In this vein, the cloud based central traffic management software can arbitrary change the PLC live running programs via Apache Kafka Messaging Protocol.

A representative realization of the designed system will be the remote management option, i.e. the traffic lights will be capable to be monitored and controlled via the internet from anywhere.
5 Conclusion

A novel road traffic management system is planned aiming to allow a fully flexible traffic signal control during vehicle and system testing at ZalaZONE Proving Ground. The methodology of the proposed traffic management system can be adopted for any other test tracks or even for real-world traffic control system. The system to be developed will also support the future customers of ZalaZONE as in this way the tests can be monitored and saved real-time. In relation with this last option, the digital twin concept must be emphasized which is also a future plan of the designed system. This work will use two simulation software packages: PTV VISSIM (a common industry software) and SUMO (open source software mostly used by researchers). The digital twin will allow to real time mimic the test tracks’ traffic light control in parallel in traffic simulation software environment. By the help of this the so called mixed reality simulation [6] and Vehicle-in-the-Loop [7] testing processes can be implemented in the future.

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