C-ITS enabled dynamic traffic management as a service

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Abstract

C-ITS enabled Dynamic Traffic Management as a Service refers to the coordinated provision of several C-ITS services as one combined suite of services and their integration into operational traffic management. Cooperative Intelligent Transport Systems (C-ITS) constitute innovative technologies, which enable information exchange among vehicles (Vehicle-to-Vehicle, V2V) and between vehicles and the roadside infrastructure (Vehicle-to-Infrastructure, V2I). The objective of C-ITS enabled Dynamic Traffic Management as a Service is to extend the exploitation of C-ITS services, by developing a framework for their use in daily operational dynamic traffic management procedures, within varying geographical areas. In this work, two different dimensions of the proposed concept are recognized, which cover the drivers and the traffic managers. The structure of this paper is as follows: first an introduction is provided, secondly the methodology is presented, and finally a case study demonstrating the application of the C-ITS enabled Dynamic Traffic Management as a Service into the real-world urban road network of Thessaloniki is presented, accompanied by the description of the related software tool.

Keywords 1

Cooperative - Connected - Automated Mobility, Traffic Managemet as a Service

1. Introduction

Road transport systems are facing multiple long-time challenges such as increased traffic congestion, reduced efficiency and reduced road safety, which are typically addressed through traffic management. Traffic management is defined as the organisation, arrangement, guidance and control of both stationary and moving traffic, including pedestrians, bicyclists and all types of vehicles, with the objective to provide safe, orderly, and efficient movement of travelers and enhance the quality of road networks (Underwood, R. T. (1990). Traffic management: an introduction.).

Nowadays, there is an increasing need for traffic management centres to adapt to disruptive trends and technologies that take place in the transport and mobility sector. Private sector business-to-consumer vendors such as service providers, data aggregators and networks operators are currently offering mobility services to assist travelers in their daily trips. Hence, they increasingly influence through these services the travelers' behavior and the traffic patterns in road networks.

Traffic Management as a Service aims to prevent a digital divide which may result from the lack of integration of such services with conventional traffic management, resulting to public authorities gradually reduced level of control over traffic and traffic management in their areas of jurisdiction. Data from road operators, public transport fleet operators, traffic lights, mobility services, social media and various apps are to some degree already incorporated into traffic management [1]. However, the exploitation of data derived from

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cooperative, connected, and automated mobility is not applied in large-scale in traffic management centers and if so it may be accompanied by complex processes and software. From an operations point of view, it is expected that traffic managers will retain their role in managing and controlling traffic by relying on the alliances formed with other parties, reshaping in this way conventional traffic management [2], [3], [4].

The work presented herein proposes an approach for coordinated dynamic traffic management by integrating C-ITS services and by promoting collaborative synergies between Traffic Management Centers and third parties. C-ITS enabled Dynamic Traffic Management as a Service is the coordinated provision of multiple C-ITS services as one combined service. The concept is developed, in order to serve both the objectives of drivers as well as network operators and traffic managers. Anticipated benefits include network optimization, effectiveness and interoperability in dynamic traffic management, and improved regulation of the provided services. The next section describes the methodology in which the C-ITS enabled Dynamic Traffic Management as a Service is based one, while the third chapter demonstrates the application of the concept in a real-life road network, and the final chapter describes a software tool which is developed for the application of the concept by traffic management centers.

2. Methodology

The concept of the C-ITS enabled Dynamic Traffic Management as a Service relies on the approach of [2] for the design of Dynamic Traffic Management (DTM) "control strategies". A control strategy is defined as a procedure which typically focuses on the prevention of congestion on road segments and on the security of policy goals by optimizing traffic flows [2].

Regarding the actual content of a control strategy, this is comprised on three building blocks:

1. Policy.
2. Road network.
3. Strategies.

A policy, which is defined by a road authority, serves as the basis for a traffic management control strategy. A policy includes the description of the importance and the function roads, as well as quantitative thresholds for parts of the road network.

The road network includes all the areas and where traffic management is applied. The purpose is to classify the road network into the following parts:

- Choice nodes, where the traveler can choose between travel alternatives. Such nodes can be used to affect traffic flow.
- Control nodes, where the capacity of one or more directions can be affected. Such nodes can be used to influence traffic flow.
- Regular nodes, where traffic cannot be affected and travelers do not have a choice between travel alternatives.
- Control segment, where the capacity can be affected. Such sections can be used to influence traffic flow.
- Links, defined as the parts between two control nodes or between a control node and a choice node. Links are used to detect traffic problems.
- Route parts, defined as the parts between two choice nodes. Route parts are used to detect traffic problems.

The strategies may fall into the following four categories:

1. Strategy 1 (S1): Inform traffic.
2. Strategy 2 (S2): Enlarge the outflow.
3. Strategy 3 (S3): Reduce the inflow.
4. Strategy 4 (S4): Reroute traffic.

Each strategy contains one or more DTM services and they are typically applied as escalation phases, the first being the least severe one and the last being the most radical one.

The DTM services considered by [2] appropriate to be implement in the road network and contribute in the successful implementation of the strategies. Conventional DTM services include metering, which contributes to reduce the inflow, and traffic traffic lights modification, which contributes to enlarge the outflow and/or reduce the inflow.

2.1. C-ITS services for traffic management

According to [5], C-ITS services are categorized into Day 1 and Day 1.5 services.

Day 1 C-ITS services include services with the objcective to provide Hazardous Location Notifications, i.e., Slow or stationary vehicle(s) & traffic ahead warning, Road Works Warning,

Weather Conditions, Emergency Brake Light, Emergency Vehicle Approaching, and with services acting as signage applications, i.e. In-Vehicle Signage, In-vehicle Speed Limits, Signal Violation/ Intersection Safety, Traffic Signal Priority Request by designated vehicles, Green Light Optimal Speed Advisory, Probe Vehicle Data, and Shockwave damping.

Day 1.5 C-ITS services include more sophisticated services, many of them being until today in an experimental phase. These services include: Information on fuelling and charging stations for alternative fuel vehicles, Vulnerable road user protection, On street parking management and information, Off street parking information, Park and ride information, Connected and cooperative navigation into and out of the city, and Traffic information and Smart routing.

This work identifies among the Day 1 and Day 1.5 services the ones, which are appropriate for implementation for traffic management purposes. The distinction relies first on the principle that such services are based on V2I technologies, enabling the infrastructure of traffic management centers to have an added value role, and second on the principle that the servics can have an impact on the strategies. The following table presents the selected C-ITS services and defines their contribution to the strategies.

Table 1
C-ITS Services for Traffic Management

C-ITS Service	S1	S2	S3	S4
Road works warning	Road works/ changes to the road layout information	-	-	-
Road hazard warning	Hazardous locations downstream information	-	-	-
Green light optimal speed advisory	Speed advice/ green wave/ time to green/red	-	-	-
In-vehicle signage	Conditions/ restrictions information	Speed harmonization	Speed harmonization	-
Traffic information and smart routing	Lanes status downsteam information	Road capacity modificaations	Road capacity modificaations	-
Probe vehicle data	Indirect effect	Indirect effect	Indirect effect	

2.2. Operational process

The objective of the operational process defined in this work is to provide guidelines, including concrete implementation steps, for the real-life integration of C-ITS services into daily operational traffic management. Based on the methodology described above, the steps are defined as follows:

1. Identification of policy objcetives.
2. Identification of the contribution, in terms of impact, of the C-ITS services to each of the four strategies.
3. Identification of the appropriate C-ITS services which apply to each part of the road network.
4. Establishment of the information exchange between road authorities and service providers on the objectives of the former and on the available services of the later.

Having completed the above steps, the operational process can be applied. An indicative example for the application of the operation process includes the case when a road operator (traffic management centre) detects a traffic jam in the network and wishes to tackle the traffic problem. The road operator chooses the strategy to enlarge the outflow by opening a peak-hour lane for drivers. The road operator provides this information to the service providers. Service providers that own a related C-ITS service, e.g, Traffic information and smart routing, provide it to their customers (drivers). These customers of the service

provider receive this information on their personal devices (e.g. smartphones, tablets) as a C-ITS service.

3. Case study

The case study presented in this work concerns the city of Thessaloniki in Greece. The city has a high number of circulating vehicles and a dense road network, resulting to several mobility challenges [6], [7]. These challenges are currently addressed through the deployment of C-ITS services through the participation of the city in the C- MobILE project, which focuses on large-scale implementation and demonstration of C-ITS services in European cities [8].

Taking into account the steps defined in the operational process, the policy objectives were identified, in order to address the most common traffic problems, i.e., traffic congestion, parking problems and accidents. The policy objcetives include:

- Accidents reduction
- Road safety increase
- Promotion of eco-friendly driving
- Provision of real-time information
- Optimization of traffic flow
- Increase traffic efficiency

With regards to C-ITS services capable of having an impact to the strategies, the following ones have been selected to be applied at city level:

- Road Works Warning
- Road Hazard Warning
- Green Light Optimal Speed Advisory
- In-Vehicle Signage.
- Flexible Infrastructure - Mode and Trip Time Advice (Traffic information and Smart routing).

The third step of the operational process is expressed through a table which provides a mapping of the C-ITS services to the parts of the road network with regards to the impact they can have on the strategies.

Table 2
C-ITS Services mapping to the road network

C-ITS Service	Road network part					
	Choice node	Control node	Choice & control node	Regular node	Control segment	Link
Road works warning					x	x
Road hazard warning					x	x
Green light optimal speed advisory		x	x			
In-vehicle signage					x	x
Traffic information and smart routing	x	x	x		x	x
Probe vehicle data	x	x	x	x	x	x

The locations of the road network of Thessaloniki, where the C-ITS services are provided are presented in the figures below.

Figure 1: Roads Works Warning and In-Vehicle Signage service provision locations

Figure 2: Green Light Optimal Speed Advisory service provision locations

Finally, the last includes the identification of the roles and the relations of the stakeholders participating in the operational process. For the case of Thessaloniki, stakeholders and the respective roles are identified as follows:

The traffic manager is represented by the traffic management center of the city, which is operated by the Region of Central Macedonia and collaborates with the service provider for the coordinated provision of C-ITS services.

The service provider is represented by the Hellenic Institute of Transport, which is responsible for the implementation of the services and the communication of the necessary data to and from the traffic management center through the appropriate software.

The end-users are represented by professional drivers of a taxi fleet company operating in the city, as well as from regular drivers using a dedicated Android application, which provides access to the above mentioned C-ITS services.

4. Tool for C-ITS enabled Dynamic Traffic Management as a Service

The application of the concept of C-ITS enabled Dynamic Traffic Management as a Service from traffic managers is achieved through the use of CTMaaS, a software tool developed by the Hellenic Institute of Transport in the framework of the C-Mobile H2020 project. The software tool is comprised of modules and applications with interfaces between traffic managers, traffic information service providers, fleet managers and individual travelers. The objective is to enhance and enable traffic management through the coordinated provision of C-ITS services, through monitoring and assessment of the set targets, and through the efficient utilization of large volumes of multi-source data.

CTMaaS is comprised of two major components: the Scenario Manager and the Dashboard. The Scenario Manager component allows the coordinated activation and deactivation of C-ITS services within the framework of Dynamic Traffic Management strategies, aiming to solve specific traffic problems.

The Dashboard component allows the visualization and analysis of real-time and multi-source traffic data. The Dashboard provides users with KPIs, line charts, bar charts, tables and digital maps, allowing traffic managers to easily monitor traffic conditions, the impact of the deployed dynamic traffic management strategies, as well as important insights of the overall road traffic operations.

5. Conclusions

The proposed work has the objective to suggest a concept which utilizes the emerging C-ITS technologies, in order to achieve the effective implementation of the goals set for daily operational dynamic traffic management. The proposed concept relies on the utilization of multiple data sources with the purpose to serve as an intermediary decision-support tool, bridging conventional traffic management and traffic information services provision.

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