

# A Novel Model Representation Framework for Cooperative Intelligent Transport Systems

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## Abstract

Cooperative Intelligent Transport Systems is C-ITS a set of ITS technologies that can provide services supported by the permanent, real time, information circulation among the components of the system. The paper aims to give an overview related to the modelling and evaluation possibilities of cooperative intelligent transportation system and to clarify the definition of the C-ITS and its differences from the regular ITS solutions. The paper introduce a proposed architecture of C-ITS modelling framework by describing C-ITS components, transferred data and its applications.

## Keywords

C-ITS, modelling, architecture, framework

## 1 Introduction

The Intelligent transport systems (ITS) hopefully implements environment-friendly, safe and secured transportation processes (Tettamanti et al., 2016) that are supported by advanced technologies related to the fields of data detection, transmission and storage, communication, and control. Accordingly ITS is applied to increase safety (Alali et al., 2018), sustainability, efficiency, and comfort. Cooperative Intelligent Transport Systems (C-ITS) can be defined as the set of ITS technologies which can provide services supported by the permanent, real time, information circulation among the components of the system. For example C-ITS can make accident-related information available such as traffic conditions, unexpected events, and weather conditions to the driver in real time (De La Torre et al., 2018).

From a structural point of view the components of Intelligent Transport Systems (ITS) provide effective cooperation to support transportation processes applying digital technologies (Xue et al., 2014). These system components can be practically placed on the side of the road, directly in the vehicles (Schramm et al., 2018), at the transportation center or somewhere in the cloud (Rizviet et al., 2017). Summing up, C-ITS involves the cooperating components of the transportation processes including the users (Gratian et al., 2018), the vehicles, the infrastructure and the operator. (European Transport Safety Council, 2017)

The difference between ITS and C-ITS is that the interaction among the components (e.g. user, vehicle, infrastructure, environment, operator, etc.) of the system plays a prior role in case of the C-ITS (Zöldy, 2018), whilst in case of the ITS the process supporting intelligence can be implemented even in case of a specific system module (Guerrero-Higuera et al., 2018). C-ITS functions become more and more efficient with the increasing amount of exchanged information. It is important to understand that C-ITS is not a tool in its own, C-ITS is a combination of rules, procedures, systems and sub-systems to enable cooperative service delivery (Favarò et al., 2018).

Actors in a C-ITS framework can communicate with any other actor to send, receive and exchange information. Individual vehicle can talk with other vehicle (V2V) or roadside stations/ infrastructure (V2I). These communications provide safer, more comfortable traffic flow and lower emission from vehicles. Fig. 1 represents a simplified comparison of ITS and C-ITS.

Sun et al. (2016) describe C-ITS architecture and the numerous stakeholders needed to be considered during the development of such architecture. They classified the C-ITS application into two groups. The first class involves the solutions supporting environmental operation related issues and the second groups contain approaches reducing risk

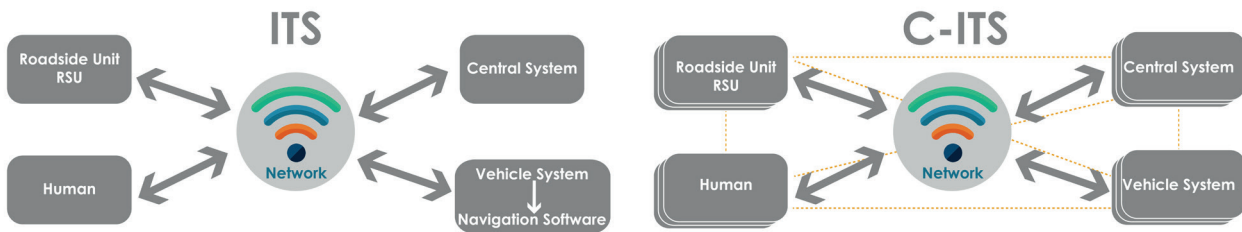


Fig. 1 ITS vs. C-ITS Systems

and increasing safety. Solodkiy and Yenokayev (2017) have studied C-ITS projects carried out in the European Union, especially focusing on the outcomes of the evaluated projects and their impact on road safety. Fouchal et al. (2017) have developed a framework that can be applied to evaluate and validate C-ITS systems (Mullins et al., 2018) the methodology takes into account all relevant C-ITS components (RSU, Vehicle, Control Centre) with their specific features.

Petrov et al. (2017) have presented the effect of C-ITS functions for a microscopic model affected by a traffic accident. The research has investigated both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, especially focusing on computer simulation and communication modelling possibilities for current and future communication technologies (VANET, 4G, 5G). The outcome of the study has showed that a lower level congestion can be achieved at the intersection by the application of advanced communication technologies, since the arriving vehicles are able to modify their route by receiving the adequate information through V2V or V2I communication channels.

Ehlers et al. (2017) have analyzed the effect of C-ITS on network safety (Hajiagha et al., 2016). They suggested a bowtie analysis as a conceptual framework for evaluating the safety effect of C-ITS. Vinel et al. (2018) have addressed the performance of V2V communications and the performance of C-ITS safety applications. Their study has evaluated the case of Emergency Electronic Brake Lights (EEBL) where a braking vehicle send data packs to the following vehicle. This function can support the other vehicles in the safely performed braking process.

Summing up, the paper aims to give an overview related to the modelling and evaluation possibilities of cooperative intelligent transportation system (C-ITS). In the next section the basic methodology of C-ITS is presented which contains C-ITS components, transferred data and its application and a small description of C-ITS simulators. The third section presents a discussion about the introduced novel methodology and a small summary in the last section.

## 2 Methodology

This section presents a brief description of C-ITS components, types of transferred data / information properties, attributes and the application possibilities. The below presented description can help the reader in understanding C-ITS and its impact on safety and efficiency on road transport system.

### 2.1 C-ITS Components

Cooperative intelligent transportation system (C-ITS) consists of several components that work together to enhance safety (Ghadi et al., 2017) and operation efficiency. In general, three main C-ITS components are differentiated: On-Board Unit OBU (in-Vehicle) uses WAVE communication method to send and receive vehicle information (e.g. Location, status, operation) to Road Side Units (RSU) or nearby vehicles. The other one is the mentioned Road Side Units (RSU) that collects various information transmitted from OBUs, stores it and transmits it to the Transport Management Centre System (TMC) or send back information to vehicles (Ficco et al., 2017). The Third component is Transport Management Center System (TMC) which consists of a C-ITS server and a big data server to process large data (Todorovic et al., 2017). TMC processes the information using the data collected through the RSU and the supporting system (Automatic Incident Detection System, Pedestrian Detection System, Tolling System, Road Weather Information System, etc.) to provide the necessary information to the driver (Ding et al., 2018).

As described above some components of C-ITS operate as a supportive systems to collect other information and send it to RSU or TMC for processing. Automatic Incident Detection System is a support system that detects unpredicted situation (fallen objects, stationary vehicles...etc.) on the road and transmits it to TMC and RSU. Smart (WAVE) Tolling Support System is used in case of multi-lanes, non-stop toll roads through the installation of WAVE communication components. Pedestrian Detection System is also a support system that detects pedestrians,

bicycles on the crosswalk area and transmits it to TMC and RSU. It can be either installed inside the vehicle or by using closed-circuit television cameras (CCTV) on roads. Road Weather Information System detects local weather characteristics and weather dependent road conditions and transfers it to the RSUs and the TMC. Traffic Signal Controller Support system controls traffic signal system in intersections such as signal phases and cycle duration in real time according to traffic condition. Fig. 2 shows a simplification of C-ITS system components.

### 2.2 Transferred Data /Information and Its Applications

Since from an operational point of view, real-time transportation processes are performed on the road (Petrillo et al., 2018), the vehicle related information exchange processes have a crucial significance in C-ITSs. Accordingly, the vehicle related communication processes are analyzed with a special attention. Two communication types are discussed: vehicle to vehicle communication (V2V) and vehicle to infrastructure communication (V2I). IEEE 802.11 WAVE standard, initiated from the allocation of the Dedicated Short Range Communications (DSRC) spectrum, provides a communication standard focusing on the channel between vehicles and infrastructure. However, there arise new innovative communication solutions almost every day. For example Bluetooth is a relatively simple communication technology and it can nearly found everywhere. Nowadays the main usage of Bluetooth related to the individual transportation to provide the conditions of a hands-free communication system that help road users to focus on the road. On the other hand, in V2I systems it can be used to provide communication channel between the vehicle and the traffic signal systems. WIFI and mobile (cellular) network technology such as GSM (Global System for Mobile

communication) can provide a capable, secured (Ghanavi et al., 2018) and reliable communication (Gopalakrishnan et al., 2018) solutions for V2X applications.

V2V and V2I improve safety and efficiency through providing information to the driver. Safety applications can be applicable based on V2V communication. These applications can warn the driver, when he or she enters an intersection or leaves the highways. In case of a complex V2V communication system hazardous locations can also be prognosticated, accidents can be reported, sudden stops can be warned, conflicts can be sensed and pre-crash warning can be activated. V2I communication increases safety in intersection, supports speed management, rail crossing operations, priority for emergency vehicles. V2V and V2I improve efficiency of the transportation network by providing information for both the drivers on the network and the operator of the transportation network. By improving the efficiency of route planning and navigation (Esztergár et al., 2015), increasing the capacity of intelligent intersections, applying smart traffic lights, automated traffic intersection controls, traffic jam notifications and prior recognition of potential traffic jams a complex C-ITS framework can significantly support the technical and economic objectives of the modern society (El Mrabet et al., 2018).

### 2.3 Simulation

The so called Vehicular Ad-Hoc Networks or VANETs represent a sub form of Mobile Ad-Hoc Networks or MANETs that provide communication between vehicles and between vehicles and other system components (e.g. RSUs deployed on the infrastructure, mobile components like drones, etc.) to support the efficient and safe transportation (Chadha, 2015). The high mobility of nodes and their behavioral patterns in a VANET networks require more realistic simulation to get reliable results, close to real life conditions (Mascareñas et al., 2017). This can be archived by combining traffic and network simulation software to perform proper cooperation.

Traffic simulation solutions are software used mainly by transportation experts to simulate various real life traffic flow conditions. Traffic simulation models can be used in VANET simulation as mobility data generators providing input for the network simulation application. Table 1 summarizes the most relevant traffic simulation model and their properties:

Network simulation models are used for simulation of numerous parameters of network traffic to describe the

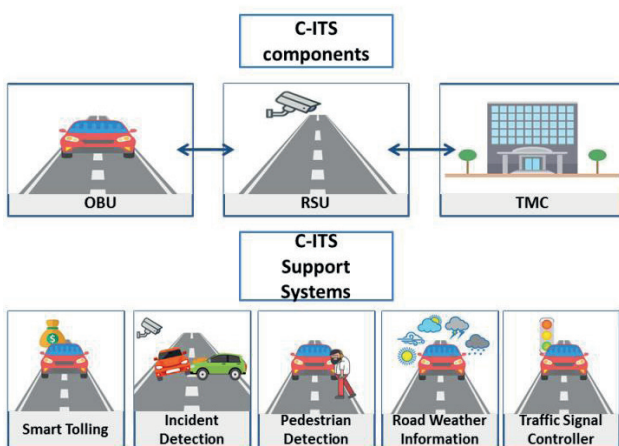


Fig. 2 C-ITS System Components

**Table 1** Traffic Simulator Properties

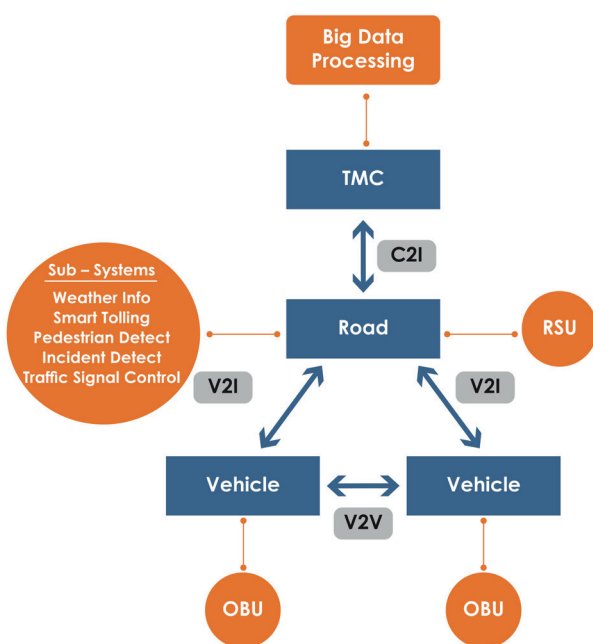
Simulator	Cost	Model	User-defined maps	Source Code Availability
SUMO	Free	Micro/Macro	Yes	Open
FreeSim	Free	Micro	No	Open
CityMob	Free	Micro	Yes	Open
Vissim	Commercial	Micro	Yes	Closed
Visum	Commercial	Macro	Yes	Closed

network behavior under various circumstances. They can also be used to optimize network topologies and communication procedures. The most known network simulation models for VANET are the OPNET, the GloMoSim, the SNS and the OMNET++.

### 3 Discussion

Based on the classification of C-ITS components, transferred data and its application possibilities it can be seen that C-ITS can provide a common framework to harmonize the operation of different system components to support a safer, a more secured (Khalid et al., 2018), a more efficient and a more reliable transport service for road users. Fig. 3 represents the C-ITS architecture.

C-ITS system improves both road safety and traffic flow efficiency at both microscopic and macroscopic level. The question is that how much the presented individual system components can improve network efficiency in case of separated operation or in case of a cooperative operation;



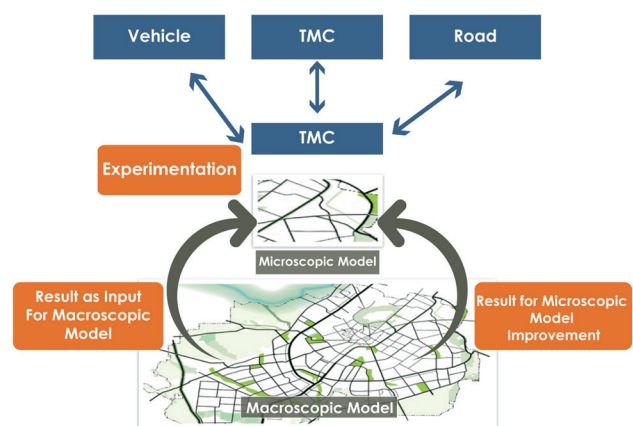
**Fig. 3** C-ITS system Architecture

for example what is the effect of transmitting traffic related data among the vehicles especially in case of congested environment or sending warning signs to the road users in case of an accident. The previous section the most relevant traffic and network simulation model gave been introduced that can be used for microscopic and macroscopic simulation. By using a combination of the presented models, the effect of C-ITS system on the network can be estimated. To design the framework which is applicable to study the mentioned effect, the paper introduces the proposed model approach in the following section. The first step is to represent C-ITS system using VANET in the microscopic fragment of the whole network and perform complex a scenario analysis to this model framework using traffic and network simulation models. The results can be used as an input for the macroscopic model to estimate the effect of the chosen C-ITS application in case of the whole network. In the next step the macroscopic model results can be used to improve the microscopic model. The introduced framework is shown in Fig. 4.

### 4 Conclusion

C-ITS is a combination of technologies that cooperate with each other to provide a safe transportation system, and efficiently share reliable, real time information related to the transportation processes among the users. Accordingly, this paper gives an overview about a proposed C-ITS system framework which makes it possible to describe the effect of the different cooperative technologies on the efficiency of transportation processes.

The paper also clarifies the definition of the C-ITS and its differences from the regular ITS solutions. In the literature review some relevant researches related to C-ITS have been presented. The second part of the paper focuses



**Fig. 4** C-ITS Modelling Framework



on C-ITS components, how these components communicate with each other and the expected effect of the cooperation. The proposed architecture of C-ITS modelling framework has been introduced using the described components, transferred data and its applications.

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