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# REDESIGNING THE FUNCTIONAL FRAMEWORK OF ROAD VEHICLES IN A SMART CITY

**Key Words**
Intelligent vehicle
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Digitization
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**Abstract**

As smart vehicles begin to roam the streets, new possibilities will emerge for large-scale data acquisition tasks necessary for proactive smart cities applications. Unlike mobile devices, smart vehicles carry powerful sensors and are highly mobile; they can cover large areas and perform high quality sensing. The road infrastructure and the information and communication environment of the vehicle need to be adapted to take advantage of the capabilities of smart city functions. This requires a holistic approach to solving the problem of digitalization of transport in a smart city environment.

## 1. DATA COMMUNICATIONS IN SMART CITY INFRASTRUCTURE

Intelligent vehicle-based smart city system consists of three components: vehicles, roadside infrastructures, and a supporting data management system. The basic building block of a sustainable smart city infrastructure entails utilizing a vast amount of data from a wide variety of sources for different purposes. Data from different sources within a smart city proximity can be used for enhancement in many areas. Taking transportation as an example, supports for the day-to-day operation of the city include various pieces of connected infrastructural equipment, fleet management system, and critical automotive components that may have a substantial impact on traffic flow and road utilization efficiency. Further, generalized extensions to public transport systems that carry a significant proportion of commuters during peak hours would require data analysis of travel pattern. Data analytics therefore entails different types, like images that show the condition of real-time traffic (the overall picture entails analysis of video footage from an array of cameras that show vehicle movement in the area), pure numerical data about public transport usage, predefined routing of each and every bus operating in the area, and the most unpredictable movement of pedestrians that exhibits a high degree of randomness. To process such diverse types of data, a communication system must be able to carry data efficiently and securely irrespective of the type and intended destination.

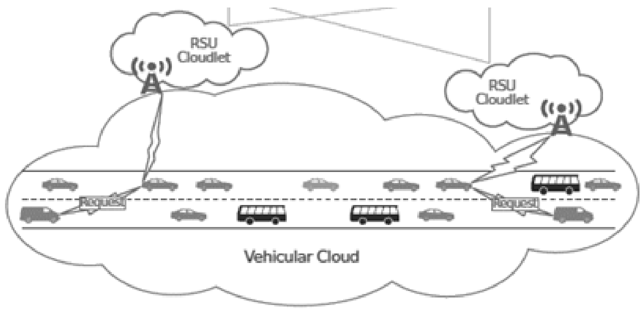


*Figure 1. Vehicular cloud defined based on its network elements[6]*

Moving into the smart city era, intelligent transportation systems entail far more than monitoring traffic flow on certain roads within a close proximity. The ITS architecture defines the framework for the development of the transport system in a small city*[3]*. Automation tasks such as electronic billing of road usage, collection of car parking fees, and electricity consumption of charging an electric vehicle (EV) should all be handled by a single payment platform. One of the key challenges is to assess data flow across the overall system, which has become a key part of smart transportation infrastructure development.

The major concerns are the ability to detect and identify events that are early warnings of traffic disruption, which could lead to eventual congestions. The ability to carry out an advance traffic assessment, data collection from multiple streams, integration and prognostication of multiple data streams for knowledge discovery, and decision-making will require a very sophisticated big data analysis platform. All of these outputs will ensure the reliability of the performance of the complex traffic analysis system.

## 2. VEHICLE COMMUNICATION NETWORK V2X

In the context of the smart city, interoperability with legacy networks and infrastructures is perhaps the greatest challenge that network planning has to deal with.This is significant as it entails more than full compliance with various networking standards. The legacy networks are not an issue by themselves, yet linking them with the smart city network backbone may entail validation of technology prior to network integration, and this may pose problems. When dealing with integration and interoperability, there is even more than integrating harmoniously between a smart city and the outside world. Smart city infrastructure should be designed such that vehicles ranging from the smallest personal mobility vehicle challenges in next generation transportation systems, several approaches and programs have recently been proposed, among them is the Intelligent Transportation Systems (ITS) concept*[7]*. Specifically, the latest ITS advances are promising to transform the system into a true Cyber Transportation System (CTS) with increased levels of connectivity among vehicles and the infrastructure (e.g., the Connected Vehicle (CV) initiative) and increased levels of vehicle automation (e.g., automated vehicles (AV) and ultimately self-driving cars). With the widespread adoption of V2X communication, smart cities are surrounded by various highly localized vehicular networks such as vehicle to vehicle (V2V), vehicle to home (V2H), and V2I. In the V2X context, the most important attribute of managing a network (or subnetwork) is constructing and maintaining network resources. Since momentous computational power is necessary to transmit and receive communication packets simultaneously, each vehicle in the V2X system may have certain limitations to share their resources by relaying packets destined for other nodes.

## 3. INTELLIGENT VEHICLE IN A SMART CITY

In the case of vehicle automation, it is possible that vehicles can safely follow each other more closely with faster reaction times while in traffic, thereby increasing the net capacity of the roadway (in terms of vehicles/hour/lane). However, it is very important to distinguish between autonomous vehicles and automated vehicles in the analysis. These two terms are often used interchangeably, however there is a significant difference when considering how vehicles interact in traffic and with associated congestion. An autonomous vehicle typically relies almost entirely on its on-board sensors to make driving decisions, just as humans do.

This is in contrast to automated vehicles, which in addition to on-board sensors, they can also take advantage of vehicle-to-vehicle communications, as well as infrastructure-to-vehicle communications. In the case of an autonomous vehicle, processing sensor information and making decisions solely on that information can sometimes take just as long as human drivers.

Automated driving is distinguished from driver assistance primarily through the role of the driver, and more specifically, through the involvement of the driver. Driver assistance systems including partially automated systems require the driver to constantly monitor the environment and to be instantaneously available to take back control from the vehicle. Automated driving systems will allow the driver to be completely out of the loop. If the driver is out of the loop, a significant amount of time may be required to return vehicle control to the driver. This challenge leads to relevant implications on the design of the automated driving system: the automated system has to make decisions in all situations and cannot rely on the driver to take back responsibility instantly. The interaction of the human driver with the automated system will be most relevant when it comes to the “handover” between manual driving and automated driving. The vehicle must monitor the driver’s position to take back control from the vehicle and must also ensure that the driver has taken back control. In case the driver fails to respond to a takeover request, the vehicle must be capable of bringing itself into a safe state. The execution of the safe state transition depends on the specific driving situation and may include changing to the emergency lane to come to a controlled stop or may result into a gradual slow down on the existing lane An automated driving vehicle needs to handle all situations within its functional scope. Driver assistance systems are typically designed and optimized for certain scenarios and often use rules to makes decision based on the detected scenarios. Automated vehicles must make reliable decisions in all scenarios Automated vehicles require combined lateral and longitudinal motion control to also ensure the desired position over time. Unlike the current generation of driver assistance systems, our control algorithms use coupled lateral and longitudinal control for improved performance. Automated Driving is a key enabling technology for increased efficiency, comfort and safety. More than 90 % of all accidents are at least partly caused by human error.

## 4. INTELLIGENT ROAD INFRASTRUCTURE OF A SMART CITY

There is a wide range of information that the infrastructure smart city can provide to connected and automated vehicles. By providing useful information about what is happening on the highways, infrastructure improves the functionality of automated vehicles and offers numerous benefits to the transportation system, including mobility, safety, and environmental benefits. These three areas are inextricably intertwined, and improvements in one area may result in benefits to the others*[6]* Congestion increases the risk of an incident occurring, which in turn leads to more congestion and fuel emissions. Similarly, where incidents occur, queues build up and may cause vehicles to stop suddenly, contributing to secondary crashes.

As noted above, connected infrastructure can provide information about impending congestion to an automated vehicle that can be used to make better route choices, dispersing traffic more efficiently across a network and improving mobility. Infrastructure can also support automation capabilities by providing managed lanes for truck platooning, which can improve the mobility of freight, thereby increasing national productivity. In addition to enriching the information environment, infrastructure may be a critical fail-safe when all other sources of information are unavailable. Connected infrastructure can contribute to safety by providing a redundant source of information that can be fused with sensors to increase the reliability of an automated vehicle. Any environment that relies upon highly sophisticated technology needs this redundancy so that if the primary system shuts down, backup systems are in place to ensure continuing functionality. Environmental benefits can also be realized through connected infrastructure. For example, the delivery of signal phase and timing information from traffic signals to automated vehicles can contribute to improved throughput and fuel savings by limiting the number of vehicles that idle at intersections waiting for lights to turn green.

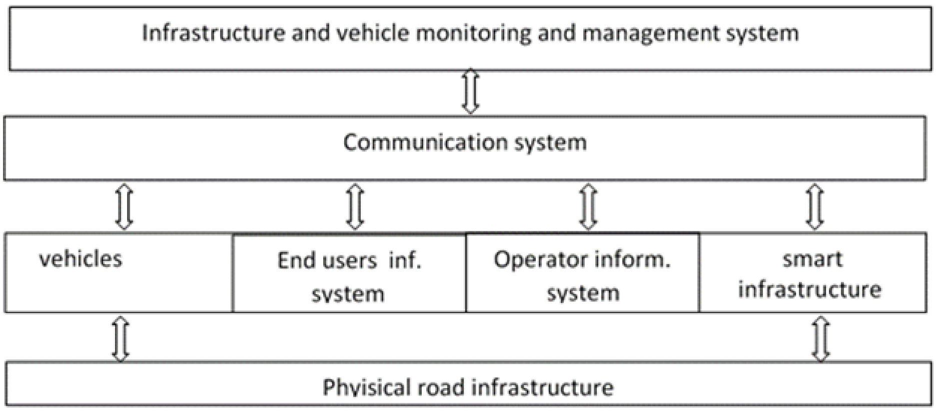


*Figure 2. Functionalities of intelligent road infrastructure [1]*

Timely infrastructure-provided information will enable new applications that are expected to be highly appealing to the buying public, thus benefitting all users of the transportation system. As intelligent infrastructure becomes increasingly deployed, automated vehicle purchases are expected to increase.

The installation of connected infrastructure may ultimately be the tipping point for revolutionary adoption of automated vehicles. Infrastructure and vehicle monitoring and management system, which automatically monitors all the other subsystems, manages the vehicle traffic and activates emergency procedures in case of malfunction. Infrastructure, whose role is to compensate the lack of performance on the onboard safety systems. End user information system, which allows end users to interact with the ARTS during normal and emergency operation. Operator information system, which allows a (human) fleet operator to remotely supervise the system operation and to intervene in case of need. Communication system, which must allow all the components communicate at all times. Automated vehicles, whose aim is to transport the passengers in a safe, secure and comfortable way from an origin station to a destination station

Our objective is to install a minimal number of RSUs on some road stretches such that every trajectory can be uniquely identified according to the received environmental evidences. More specifically, considering that some RSUs may use the same transmitting powers or time-dependent random numbers, here we focus on the distinguishability exclusively based on RSU identity numbers within the environmental evidences. Generally, the optimal placement of RSUs must guarantee three conditions. First, a minimal number of RSUs are deployed on certain road stretches. Second, the vehicles traveled along different routesmust be distinguishable according to their received environmental evidences' RSU identities. Last, considering that an adversary may intentionally drop certain RSUs' messages in order to create fake location claims, a flow's tag sequence cannot be the subsequence of any other flow's received tag sequence.

## 5. CONCLUSION

The development of the smart city requires a change in the environment of road vehicles, which includes intelligent roads and intelligent vehicles. This can be achieved by developing intelligent transport systems. The ITS architecture defines the framework for the development and implementation of ITS services. It is necessary to integrate the functions of the transport system and the intelligent city on a functional and physical level. This requires the inclusion of intelligent transport systems in all phases of smart city development from the planning, implementation implementation design and measurement of the effects of smart city functions on the transport system. In order to achieve the desired goals, it is necessary to transform the physical transport infrastructure into digitalization infrastructure. The digitized infrastructure will enable the interaction of road vehicles, drivers and transport users with the environment in a more efficient way, which will increase the efficiency of the transport system in the smart city.

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