Cooperative ITS Solutions for Standstill Vehicles in Road Tunnels
A state-of-the-art report

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Abstract

The Stockholm Bypass tunnel will be one of the longest in the world that is expected to be available in 2025. In this type of tunnel, traffic safety is a highly prioritized subject. In addition to the technology currently used for these purposes today (e.g., video cameras), new Cooperative Intelligent Transportation Systems (C-ITS) have shown potential of improving safety by allowing communication between vehicles and the tunnel infrastructure and enhance communication with other road users as well as the traffic management centers.

As an important step in this work, the Stockholm Bypass project has been granted co-funding for research from the European Union through the Trans-European Transport Network (TEN-T). The aim of this study is to explore the role of C-ITS when it comes to detection and handling of standstill vehicles in long road tunnels such as the Stockholm Bypass tunnel. The study is based on a literature review of current research and development in the area.

The literature review reveals that detection of standstill vehicles in road tunnels by means of cooperative intelligent transportation systems (C-ITS) is a relatively unexplored area. However, detecting such vehicles in other traffic environments such as highways has been addressed in several research projects, showing the great potential of cooperative solutions.

One of the major challenges for C-ITS addressing standstill vehicles in long road tunnels such is accurate localization due to lack of GPS signals. Though the current ITS-Station development focuses on positioning methods by GPS, other positioning methods are expected to be integrated if GPS signals are not available. Since it can be assumed that no GPS signals are available within the tunnel, the only method that we can consider is wireless network based positioning.

Which type of communication will be used in our future transportation system is to a high extent affected by developments and trends in other fields such as telecommunication and information technology. Cellular communication is widely used today in Sweden and there are indications that a great majority of vehicles will be connected by means of 4G/LTE by 2025, and new generation of such networks is being developed. However, it is not feasible to expect that the deployment rate will reach 100 percent. Dedicated short-range communication (DSRC) is becoming more common and it will, in accordance with vehicle manufacturers plans, be deployed in some vehicles with start next year.
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1 Introduction

Detecting and managing standstill vehicles in traffic at an early stage is an important safety feature. Collisions with such vehicles may be very severe [1] [2], but they can also cause other incidents. In addition, standstill vehicles can cause traffic congestions resulting in a large socioeconomic cost and environmental impact. This is especially valid for road tunnels, where consequences of standstill vehicles are in general more serious.

Currently implemented traffic management approaches for road tunnels primarily make use of infrastructure-based measures, including sensors and traffic management centers. Vision-based cameras are typical examples of sensors that are used to provide traffic management centers with information about standstill vehicles in tunnels. In some cases, image processing software ([3], [4], [5]) is used for automatic detection of such vehicles. Video cameras as well other infrastructure based technologies have limitations ranging from coverage problems to cost and impact by environmental conditions and occlusions.

New Cooperative Intelligent Transportation Systems (C-ITS) have the potential of improving safety by allowing communication between vehicles and the tunnel infrastructure and enhance communication with other road users as well as the traffic management center. Such systems are in general referred to as cooperative systems and are based on some type of wireless communication.

The aim of this report is to give an overview of the existing digital strategies and corresponding technologies that can be used to detect and track, dangerous goods in road tunnels and to inform road users about them. A special attention is given to the future C-ITS technologies since the results will in a later stage be used to suggest possible strategies for handling of standstill vehicles in the Stockholm Bypass tunnel.

The Stockholm Bypass is a new tunnel project in Sweden, located west of Stockholm (Figure 1). The tunnel will consist of three lanes in each direction and there will be three exits and three enters. There will be emergency exists (every 150 meters) as well as extensive safety equipment such as road signs, emergency phones and fire-extinguisher. With its length of 18 km, the Stockholm Bypass tunnel will be one of the longest in the world. The development of the tunnel will start during the year and is expected to be ready for operation in 2025. It is estimated that the tunnel will be used by 140,000 vehicles per day by 2035 [6].

The Stockholm Bypass project has been granted co-funding for research from the European Union through the trans-European transport network (TEN-T). The research
The project contains several parts and will be finalized by the end of 2014, although some parts will be reported earlier.

The rest of the report is organized as follows. First, a short description of the method applied in the study is given. Next, a summary of the current principles for detection of standstill vehicles is given, followed by detailed description of communication and localization technologies. The report ends with a review of relevant research initiatives, and conclusions.

![Figure 1 Schematic view of the Stockholm Bypass tunnel.](image)

## 2 Method

This study is based on an extensive literature review. The focus of the literature review was on selecting peer-reviewed literature addressing C-ITS for standstill vehicles (e.g., journal articles, conference proceedings) and reports written within relevant projects (e.g., EU-projects). A minor number of other publications is included, due to being either extensively referenced or for giving a more detailed description of the topic. The literature reviewed is written either in Swedish or English.

## 3 Current detection of standstill vehicles

A vehicle can become standstill due to a range of reasons such as an accident, vehicle malfunctions, or driver illness. The ETSI Basic Set of Application (BSA) has defined two reasons: accident and vehicle problem [7]. Depending on the reason different solution may be needed as well as different strategy for handling of such vehicles (e.g., how they are removed from in the best way).

Currently implemented traffic management approaches for road tunnels are primarily making use of infrastructure-based measures. Vision-based cameras are commonly used to provide traffic management centers with information about standstill vehicles in tunnels. In some cases, image processing software is used for automatic detection of
such vehicles and estimation of their characteristics such as speed, size, and type (e.g., [3], [4], [5]).

Other examples include infrared beacons [8], various types of inductive loops positioned under the road surface [9], radars [10], or a combination of two or more of these technologies [11], [12]. Detection of standstill vehicles is also possible by means of vehicle-based sensors, e.g., vehicles equipped with forward collision warnings and emergency braking systems can detect and help drivers avoiding collisions with standstill vehicles. However, each of these approaches has its own limitations ranging from coverage problems to cost, penetration level, and impact by environmental conditions and occlusions. The literature reviewed reveals that detection of standstill vehicles in road tunnels by means of C-ITS is, on the other hand, a promising complementary solution that can eliminate several of these shortcomings.

Two major enablers for C-ITS for detection of standstill vehicles are localization and communication technologies. These are described in the following sections.

4 Wireless communication technologies

Wireless communication technologies are changing at a fast pace. The diversity of needs has stimulated a corresponding diversity of communication solutions and systems based on these. It is expected that beyond 2020, wireless communication systems will need to support more than 1.000 times today's communication [13]. Similarly to other domains, vehicle manufacturers and suppliers are looking to introduce functions based on wireless communication in their vehicles and services to enhance the experience of owning and driving a vehicle. According to the analysis presented in [14], in the time period 2023-2030 about 84% of vehicles are expected to have a connectivity solution (e.g., by means of integrated devices, nomadic devices).

This following sections present major characteristics of wireless communication technologies that may be useful when it comes to applications related to standstill vehicles.

4.1 Cellular networks

Cellular networks are widely used today. Their advantages are the large number of end devices in use and relatively good network coverage. Disadvantages are the high connection costs and the low transmission rates. However, technology developments that we have witnessed in the last years indicate that the cost and transmission rates may be significantly improved in the coming years. Consequently, cellular networks are expected to be an integral part of future C-ITS.

Early generations of cellular networks (1G-3G) are mainly designed for voice data exchange, which makes them less appropriate for ITS applications that are time-critical
and require high rate and broad bandwidth. For example, latency increases and reliability decreases for text data since voice data have higher priority.

The fourth generation network or long-term evolution (4G/LTE) is the current state-of-the-art terrestrial cellular broadband and addresses these drawbacks to some extent. It is adaptable to a wide range of radio bands and is recognized as a platform for communications requiring broadband data. That is, LTE can deliver infotainment types of applications far better than its precursors.

IHS Automotive forecasts that the number of LTE-connected cars worldwide will grow from 1.2 million in 2015 to 16 million in 2017 [15]. The fifth generation network (5G) is currently under development and there is for now no specified date for its deployment; some research communities and equipment manufacturers are aiming for 2020 [13] [16], while some others believe that the deployment will occur first around 2025 [17].

Basically, 5G will be an integration of existing wireless communication technologies and complementary new technologies. The evolution of existing technologies such as LTE and Wi-Fi will thus be key enablers of 5G system [13]. In comparison to the existing networks, Mobile and wireless communication Enablers for the Twenty-twenty Information Society (METIS) [18] defines requirements that 5G is expected to fulfill in the following way:

- 1000 times higher mobile data volume per area;
- 10 to 100 times higher number of connected devices;
- 10 to 100 times higher typical user data rate;
- 10 times longer battery life for low power MMC; and
- 5 times reduced end-to-end latency (maximum 1 ms latency).

The 5G system is, in other words, expected to provide efficient and high-performing communication that supports a range of different services, including cooperative ITS [13][16]. To accommodate all these requirements, Ericsson [13] and METIS [18] anticipate introduction of ultra-dense networks with nodes/base-stations operating with very wide transmission bandwidths (several 100 MHz) in higher-frequency bands (10-100 GHz). More specifically, these networks will consist of low-power access nodes being deployed with much higher density than the networks of today (e.g., at lamppost distance apart). These nodes could also be placed on vehicles. With these additions to the existing mobile network, data flows from the big base-stations are expected to become more effective at the same time as the distances to the users become shorter. Consequently, this will result in faster data traffic.

4.2 Dedicated Short Range Communication
Dedicated Short Range Communication (DSRC) is a communication service intended for fast and reliable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) information exchange at the frequency of 5.9 GHz (in Europe). The DSRC systems consist
of Road Side Units (RSUs) and/or the On Board Units (OBUs) with transceivers and transponders.

The DSRC standards specify the operational frequencies and system bandwidths, but also allow for optional frequencies which are covered (within Europe) by national regulations. In particular, IEEE 802.11p standard, which specifies medium access control and the physical layer for the future ITS, is developed. However, the fundamental characteristics of the physical layer are still an open question. In Europe, 802.11p was used as a basis for the ITS-G5 standard, supporting the GeoNetworking protocol for V2V and V2I communication. The ITS G5 and GeoNetworking are standardized by the European Telecommunications Standards Institute group for Intelligent Transport Systems (ETSI).

The DSRC systems are used in the majority of European Union countries, but these systems are currently not totally compatible. Therefore, standardization is essential in order to ensure pan-European interoperability. Standardization will also assist the provision and promotion of additional services using DSRC, and help ensure compatibility and interoperability within a multi-supplier environment. The work by standardization organization such as the ETSI, IEEE, and ISO is thus of utmost importance. According to [14], by 2024, factory fit DSRC-equipped vehicles could rise to 30%, enabling widespread data communications services and a large national DSRC infrastructure. However, it is still unclear who will pay for such an infrastructure.

4.3 RFID
Radio Frequency Identification (RFID) refers to small electronic devices that in principle consist of a microchip and an antenna, enabling readers to capture data on the chip and transmit it to a computer system [19]. A typical capacity of such a chip is about 2 000 bytes of data. The simplest RFID devices (Class 1) are passive, while the more advanced (Class 2 and higher) incorporate a battery and they may also include different communication interfaces like WiFi and 3G/4G.

This type of technology offers advantages of non-touch identification, long-distance communication, and working in a variety of harsh environments. These features have been attracting more and more governments and organizations to invest it. Nowadays RFID has been applying to gate guarding systems, inventory management, goods tracking and intelligent speed test.

4.4 ZigBee
ZigBee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. It is based on an IEEE 802.15.4 standard. The ZigBee protocol has been created by member companies of the ZigBee Alliance.

Though its low power consumption limits transmission distances to 10–100 meters line-of-sight, ZigBee devices can transmit data over long distances by passing data through a
mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking. ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

5 Localization technologies

Broadly speaking, positioning methods include mainly satellite based and wireless radio signal based. Each of them, including their advantages and disadvantages, are briefly described in the following sections.

5.1 Satellite based positioning

Surface and outdoor positioning mostly are satellite based and rely on signals from satellites. Examples include Global Positioning System (GPS) from US, GLONASS from Russia, BeiDou from China and Galileo from EU. With proper support from ground stations, satellite based positioning system can provide very accurate locations, however, they all require visibility to satellite signals.

In the case of Stockholm Bypass tunnel, satellite signal will mostly be very limited because of the tunnel length. Vehicles may keep tracking themselves for a certain time through inertial navigation system after they enter the tunnel, however, this will not last. For short duration GPS outages lasting a few seconds, devices can make use of inertial navigation units to predict the location of the vehicle. These units contain a number of accelerometers, gyros, and angular rate sensors that can be combined with mathematical models of vehicle dynamics to take the vehicle’s position at loss of GPS and estimate the position further for a few seconds. Because of noise and error build-up in the sensors, the accuracy of the estimated position degrades the longer the estimation runs. Currently there are no long-term solutions for extended-duration GPS outages.

5.2 Radio signal based positioning

Radio signal based positioning are based on radio signals from the deployed infrastructures, e.g. WiFi hotspots, cellular network base stations, etc. [20][21]Radio signal based positioning is especially useful when there is no satellite signal such as indoor environments, underground, tunnels. Radio signal based positioning methods will be the most appropriate positioning methods. Potential radio signal based positioning methods are listed below, with general comments on their advantages and drawbacks.

Cellular network based positioning (e.g., GSM, UMTS, LTE, 5G) relies on existing cellular network infrastructures. The methods require that vehicles are able to receive cellular network signals, e.g. have a SIM card onboard. Depending on the positioning algorithm, different accuracies can be achieved.
A simple proximity sensing such as cell-id based methods detects positions based on the location of the base station and is able to achieve a hundred-meter accuracy. More advanced methods, such as triangulation and trilateration of the received signals, fingerprinting based on the received signal strength, or hybrid methods can achieve a better accuracy below one hundred meters. Those statistics are based on the current public cellular networks with no optimization for the positioning purposes and can be improved with future cellular networks.

Positioning accuracy based on cellular networks depends on the density of cellular towers. In dense scenarios such as urban cities, the positioning accuracy can be improved significantly, especially with the help of digital maps. Future cellular networks, such as in 5G, small cells may be deployed with a high density within the tunnel for providing a required level of coverage and capacity. In such cases, cellular network based positioning methods may provide very accurate results as to the level of meters or even better.

Besides cellular network, wireless local network also provides different methods for positioning without satellite signals. Typical methods include WiFi/WLAN, Bluetooth, Ultra Wide Band (UWB). The positioning methods based on wireless local networks are very similar to that of the cellular networks such as proximity positioning, signal triangulation or trilateration, fingerprinting, etc. Since cells in wireless local network may cover very small areas, high accuracy localization can be achieved.

WiFi is one of the commonly used indoor positioning methods that provides an accuracy of up to certain meters. It deploys WiFi hotspots for the purpose of positioning and WiFi signal are used for devices to locate themselves. Due to the penetration of WiFi devices, a large number of commercial products are available based on WiFi positioning. Besides, hybrid methods combining cellular signals and WiFi signals may provide even better location results. Considering that WiFi may have very high penetration in future and vehicles may also have WiFi on-board, e.g. 802.11p based dedicated short range communication, WiFi may provide an cost effective method for tunnel positioning. Besides, it also provides the services such as data communications.

Bluetooth is a short range communication and can provide very accurate positioning. In the High Accuracy Indoor Positioning (HAIP) developed by NOKIA, up to 0.5m accuracy can be achieved. If combined with 3D maps, up to 10cm accuracy can be achieved. The deployment cost of such a system may be high as it needs a large number of Bluetooth transmitters and vehicles must have receivers for the purpose of positioning.

An emerging technology is visible light communication (VLC), see [22]. Besides providing a new way for wireless communications, VLC also provide an alternative method for localization. VLC based positioning methods deploy LEDs for the purpose of both illumination and communication. Illumination and communication are then used for localization. VLC based positioning system is integrated with the lighting system,
which requires no extra infrastructures. For localization, light sensors are needed and may also be integrated with the vehicles’ lighting system. VLC based positing has been shown to achieve accuracy below one meter. Considering the high density of lights within the tunnel, high accuracy of positioning may be achieved. This method will mostly depend on the development of VLC industry. If VLC communication penetration is not high enough, deployment cost of such a system may be high.

Another similar positioning method is based on Ultra Wideband (UWB). The system needs deploy UWB locaters and tags. Representative system such as Ubisense can achieve positioning accuracy up to 15cm. However, dedicated device are needed for UWB positioning and the deployment cost may be very high.

Other short range communication based localization methods include RFID, ZigBee that can provide one meter level accuracy. However, they all need dedicated devices both at the infrastructure and the vehicle sides.

6 Relevant research initiatives
This section provides an overview of relevant research initiatives.

6.1 ETSI
The European communication organization ETSI has in its Basic Set of Application (BSA) specified two applications directly addressing standstill vehicles: Stationary Vehicle – accident and Stationary Vehicle – problem [7]. This has stimulated several stakeholders to address the topic of standstill vehicles.

6.2 CAR 2 CAR Communication Consortium
The non-profit organization CAR 2 CAR Communication Consortium has listed a function called Stationary Vehicle Warning, V2X Rescue Signal [23] as one of the functions based on vehicle-to-vehicle (V2V) communication that is likely to be introduced in the soon future. The functions will be based on the dedicated short range communication (DSRC) as defined by the ETSI, i.e. communication standard 802.11p. However, other characteristics of the function are still unknown since it is up to each vehicle manufacturer to define own functions. Other functions that may be relevant for the detection of standstill vehicles in road tunnels that are listed in [23] include Hazardous Location Warning and Traffic Jam Ahead Warning. To speed up the implementation of these and similar day-one cooperative ITS functions, a strategic alliance named the Amsterdam Group [24] has been initiated.

6.3 ETTE
The Swedish research project ETTE has recently demonstrated a function called Stationary Vehicle Warning. It is based on V2V communication between a truck and a passenger car [25][26]. If the truck becomes standstill, its driver activates the function via an in-vehicle button that transmits its position and warning to the driver in the passenger car, and vice versa. The function makes use of the ETSI standard (802.11p)
for vehicle-to-vehicle communication as well as cellular networks (3G/4G LTE). Currently, the function does not incorporate any vehicle-to-infrastructure communication and is therefore not targeting traffic management and other stakeholders that may benefit from such information.

A natural step in the further development of the function would be to enable vehicle-to-infrastructure communication and define how to use this type of information to make handling of standstill vehicles as efficient as possible. Given that road tunnels are unique traffic environments, the function should also be evaluated under such conditions with a special focus on driver behavior, acceptability, positioning and communication. To start with, the evaluation could be carried out in simulators, but it is important to perform evaluations under more realistic conditions (e.g., in an existing road tunnel).

Figure 2 Stationary vehicle warning developed by ETTE [25].

6.4 eCall
European research and development project Heero is creating eCall that is an emergency call system integrated into vehicles aiming at reducing the amount of people killed in road accidents [27], see Figure 3. The system will be mandatory in cars in Europe from 2015. The principle of the eCall is as follows:
• When vehicle-based sensor detect a serious crash, the function is triggered automatically;
• The system dials the European emergency number;
• It establishes a telephone link to the appropriate emergency call center and sends details of the accident to the rescue services, including the time of incident, the accurate position of the crashed vehicle and the direction of travel (most important on motorways and in tunnels).

The function can also be activated manually by pushing a button in the car, for example by a witness to a serious accident. In case of an accident in a road tunnel where the GPS signal is poor or absent, the eCall will transmit two latest position estimates. The age of data in long tunnels may therefore be an issue and shortcoming of the function.

![Figure 3 Schematic view of eCall [27].](image)

### 6.5 Virtual tow
Development of automated driving opens new opportunities for reducing consequences of standstill vehicles, especially those caused by driver illness. Honda has recently demonstrated a C-ITS function that a driver can activate in case of inability to continue driving [28]. When activated, the function allows the vehicle in front to take over steering control. That is, the vehicle in front becomes the lead vehicle in a platoon. The applicability of such a function for road tunnels is not addressed.
6.6 SAFE TUNNEL
The SAFE TUNNEL project has developed a function called Diagnosis and Prognosis [29] that analyses the vehicle malfunction codes and in case of an anomaly sends warnings to the driver. In addition, the function is applying a predictive algorithm and transmitting relevant information to a traffic management center. The malfunctions are briefly divided into three groups, where one of the groups relates the malfunctions that can lead to a stop (e.g., problem to engine control system, reduced fuel autonomy). The information to the traffic management center is transmitted by means of a GSM/GPRS link. However, the architecture of the systems has the GPRS modem as a specific module meaning that a migration towards the 3G/4G LTE technologies could be easily realized.

6.7 SAFESPOT
The research project SAFESPOT has suggested a function called Hazard and Incident Warning [30] that provides vehicle drivers with a warning of potentially dangerous events or conditions affecting the road ahead. The dangerous events or conditions include stationary vehicles, queues, accidents, animals or pedestrians on the road. The system combines information that vehicles and a vision based camera positioned in the infrastructure transmit to a road side unit (RSU) dangerous events or conditions are detected. The RSU broadcast then warning to vehicles by using dedicated short range communication (DSRC).
6.8 WILLWARN
The research project WILLWARN has suggested a function called Wireless Local Danger Warning [31] that is based on V2V communication for detection of obstacles and other hazards on the road. The system detects hazards by means of onboard sensors and algorithms, and then transmits the information the vehicles in the vicinity. After combining remote and local information, the relevance of the hazards is evaluated by comparing the vehicle’s trajectory and the position of the incident. Finally, a hazard classification rule decides when and how to inform the driver about a certain incident.

6.9 COOPERS
In another European project called COOPERS a range of services (e.g., accident/incident warning, weather condition warning, in-vehicle variable speed limit information) were developed and tested in road tunnels.

6.10 CVIS
The European project CVIS (Cooperative Vehicle-Infrastructure Systems) aimed at designing, developing and evaluating technologies needed to allow vehicles to exchange information and cooperate with each other as well as with the roadside infrastructure [32]. The project developed a reference platform providing wide-ranging functionality for data collection, journey support, traffic and transport operations and driver information (Figure 5).

![Figure 5 CVIS high-level architecture [32]](image)

6.11 Intelligent Access Program
Australian Intelligent Access Program (IAP) is a voluntary program based an off-the-shelf in-vehicle system that is used to monitor heavy vehicles’ road use [33]. More
specifically, it uses a combination of satellite tracking (GNSS) and wireless communications technology, Figure 6. Hardware installed for IAP includes an in-vehicle unit and a self-declaration input device. The in-vehicle unit automatically monitors and stores information, such as: date, time, vehicle position, vehicle speed, potential malfunctions, and attempts at tampering, which it can relay to government agencies. The self-declaration input device allows the vehicle operator to input information and explain behavior that may appear to be non-compliant to the regulations.

![Figure 6 Basic principle of the IAP [34].](image)

7 Conclusions

The literature review reveals that detection of standstill vehicles in road tunnels by means of cooperative intelligent transportation systems (C-ITS) is a relatively unexplored area. However, detecting such vehicles in other traffic environments such as highways has been addressed in a range of research projects, showing the great potential of cooperative solutions.

The European communication organization ETSI has in its Basic Set of Application (BSA) specified two applications directly addressing standstill vehicles: Stationary Vehicle – accident and Stationary Vehicle – problem. Car2Car Consortium has also included a function called Stationary Vehicle Warning in its list of the prioritized functions, i.e. functions that vehicle manufacturers will develop in the coming years. In addition, eCall function that will mandatory for all new vehicles in Europe from 2015 is addressing standstill vehicles caused by accidents. Several research projects, including the Swedish project ETTE, are either directly or indirectly exploring the topic of standstill vehicles.
One of the major challenges for C-ITS addressing standstill vehicles in long road tunnels such as the Stockholm Bypass tunnel is accurate localization. Given that GPS signal is poor/absent in such environments, other localization methods are required. In the current development of cooperative intelligent transportation system, positioning is part of the basic services of the ITS-Station that resides within the future vehicles and is responsible for communication services. Though the current ITS-Station development focuses on positioning methods by GPS, it is expected that other positioning methods to be integrated if GPS signals are not available. Considering the time frame for Stockholm Bypass tunnel and the technology advancement in the coming years, localization facilities may need to be planned from the very beginning. Since it can be assumed that no GPS signals are available within the tunnel, the only method that we can consider is wireless network based positioning.

Communication technology is an area that is in a continuous development and several stakeholders are trying to set the stage. Which type of communication will be used in our future transportation system is to a high extent affected by developments and trends in other fields such as telecommunication and information technology. Cellular communication is widely used today in Sweden and there are indications that it will continue to expand. Based on the current development and deployment rates of 4G/LTE, a reasonable assumption is that a great majority of vehicles traveling on our roads will be connected with this technology by 2025 (the time point when the Stockholm Bypass tunnel is expected to be ready for public use). However, it is not feasible to expect that the deployment rate will reach 100 percent. In addition to the development of cellular networks, dedicated short range communication (DSRC) is becoming more common. In the beginning of 2014, the European organizations ETSI and CEN finalized the definition of a basic set of communication standards for cooperative vehicles (802.11p). This is expected to accelerate development and deployment of functions based on this standard
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